Centre for
Energy Studies

HIGH TEMPERATURE CORROSION EROSION TEST FACILITY - INSTRUCTION MANUAL

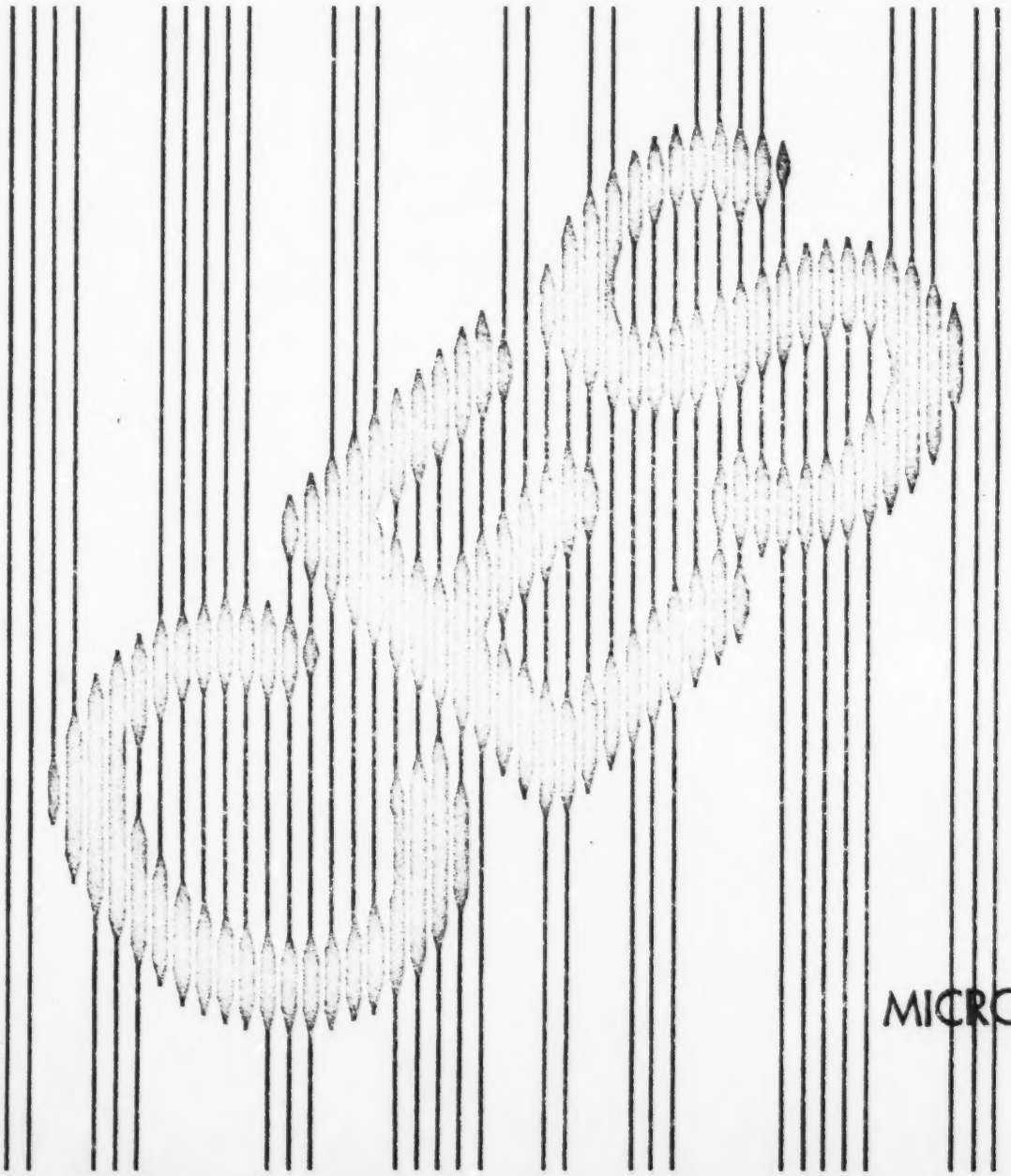
Designed and Constructed by CES
Technical University of Nova Scotia

Contract: 23440-2-9084

Project: 435051

DSS: OSQ82-00126

G. S. Trivett
G. Murphy
G. Park



58 pp

MICROMEDIA
MAR 15 1985

CES HIGH TEMPERATURE EROSION TESTER

Instruction Manual

1) Introduction

2) Installation

3) Experimental Procedure

4) Theory of Operation

5) Software and Electronics Documentation

6) Theory of Operation, Control System Interface

7) Data logs from acceptance tests

PMRL CANMET HIGH TEMPERATURE EROSION TESTER

Designed and Constructed by
The Centre for Energy Studies
Technical University of Nova Scotia
1984

INSTRUCTION MANUAL

This facility is designed to control the necessary experimental parameters to allow accurate determination of the corrosion-erosion performance of materials over a wide range of temperatures, gas compositions and particle types and sizes. The operation of the rig is computer controlled and monitored. This manual must be used in conjunction with the following literature provided by component manufacturers to allow successful operation of the device. It is the responsibility of each operator to completely familiarize himself with this manual and those listed before attempting to use the rig.

Required Reading

IBM PC Guide to Operations, sections 1, 2, 3.

Operating and Maintenance Instructions Sylco Fine Powder Feeding Apparatus Mark IX

Epson MX-80 printer manual

Required Utilities

230 volt 60 amp single phase, Arklite AR631-M72 model receptable.

120 volt 15 amp service, surge protected and voltage stabilized as required by IBM for use with a PC.

Cold water 40 psi, 2 liters per minute.

Gas bottles, manifolded to provide adequate volume for required experiment duration, at a feed pressure of 20 psi maximum, and 10 psi nominal for powder feeder carrier gas.

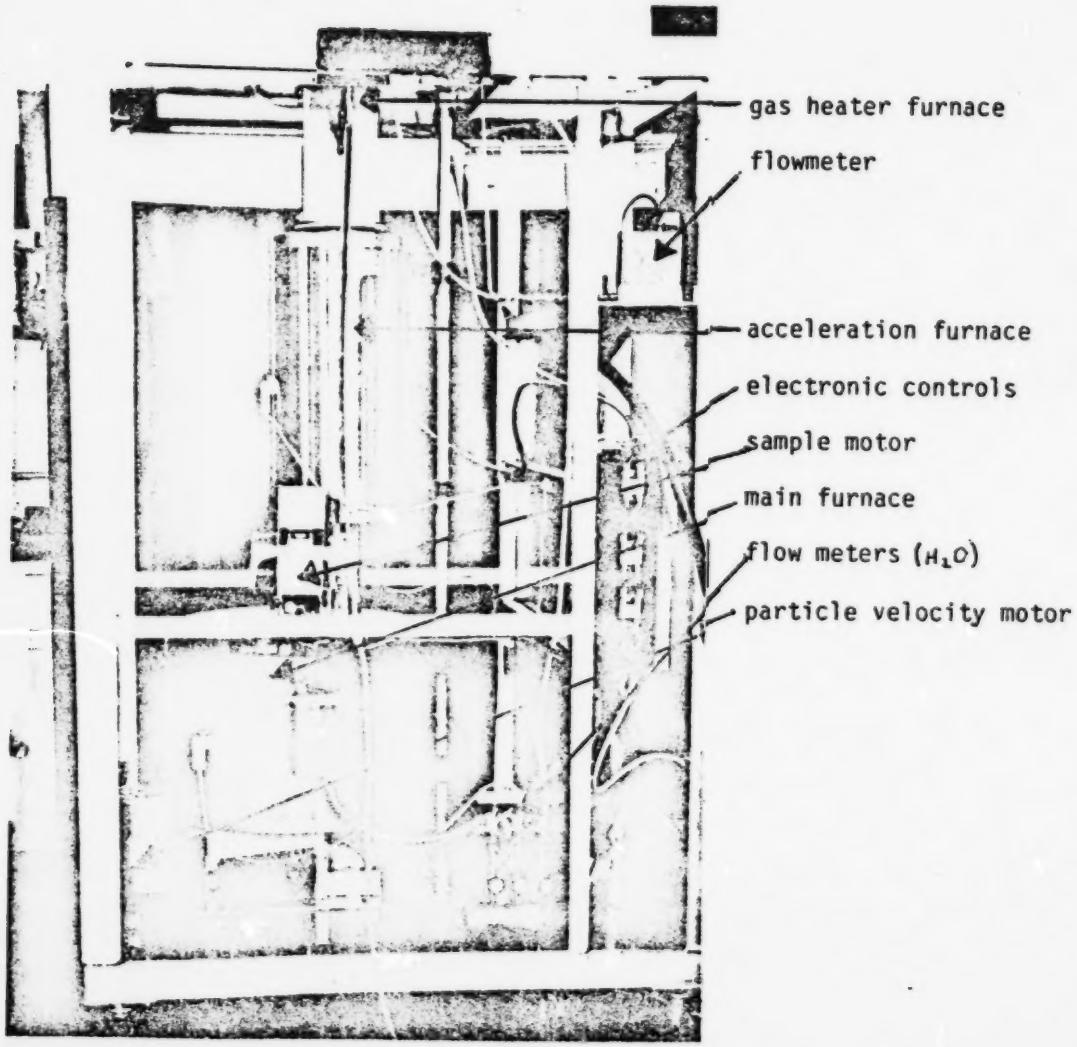
120 volt variac to control shop vacuum spent powder collector.

Adequate safe ventilation, preferably a fume hood to exhaust all gases which escape from the sample chamber. It is the responsibility of the operator to ensure that dangerous gases are completely vented away from the area.

Installation

The rig is equipped with locking casters. Remove all packing material and shipping restraints and position the rig in the chosen location. Figure 1 shows the rear of the rig. Note the 3 valves and flow indicators in the lower right of the photo. Connect a standard garden hose to the inlet shut-off valve located directly below. Connect a second hose to the fitting on the water cooled bearing supporting the bottom shaft into the sample chamber and connect the other end of the hose to a drain. This fitting is located below the bed plate of the rig. Connect the inlet hose to a suitable water line, open both the inlet and outlet shutoff valves and turn on the water. It is usually necessary to open the feed tap fully and rapidly to start the flow indicators moving and then to turn the flow down to approximately 1.5 gpm. Adjust the flows to the 3 individual cooling paths to be roughly equal

Figure 1 - Major Components



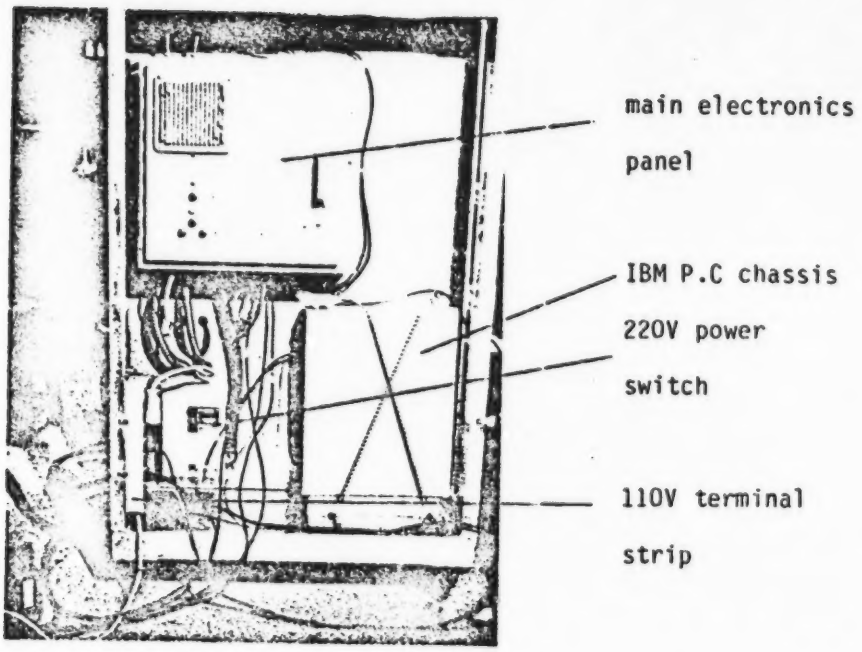
using the balancing valves and flow indicators. A strobe light can be used on the flow meters to accurately determine flow, but this is not usually required. Examine all connections on the flow paths for leaks and tighten any poor connections. This water cools 4 critical areas:

1) the Johnson Freewheeler bearing supporting the lower (velocity measurement disc) shaft;
2) the bearing supporting the upper (sample holder) shaft;
3) the electronic connection to the ceramic powder velocity detector at the bottom of the main sample furnace;
4) the rubber seals of the GTE Sylvania serpentine gas heater at the top of the rig.

Plug in the main 230 volt power cord, ensuring that the main power is switched off at the junction box shown in Figure 2, beneath the main electronics box. Plug in the 120 volt terminal strip shown at the lower left in Figure 2. Unpack the IBM PC main unit and clamp it firmly into the foam mounts as shown in Figure 2, using the shock cords supplied. The 3 ribbon cables leading out of the bottom right of the main control box should be connected to the appropriate connectors on the rear of the computer chassis. Connect the printer and Comrex monitor as shown in the IBM manuals, and plug all the computer power lines into the regulated supply.

Unpack the Sylco powder feeder and test according to the manufacturers manual. The feeder has been modified to incorporate a mass flow meter in

Figure 2 - Electronics



the feed gas line and a screw feeder rotation monitor, both of which interface with the computer through the main control panel. Attach the wires onto the appropriately labelled connectors in the main panel.

Unpack the GTE gas heater and carefully insert it into the insulated container at the top of the rig as shown in Figure 3. Insert the output from the main Matheson mass flow meter, located on the left on the shelf above the electronics panel in Figure 2, into the heater using the right angle connector provided. Seal the connection with a thin bead of silicone rubber, and allow 24 hours drying before pressurizing.

It is recommended that a common gas mixture be used as the main test gas and the particle feeder carrier gas. Separate regulators should be used to control each flow, to maximize the flexibility of control available. The Sylco manual should be used as a guide to the connections required if combustion gases are to be used. There is a completely separate circuit for use with up to 500 SCCM of SO_2. The SO_2 supply should be connected to small flow meter to the right of the main flow meter in Figure 2. Failure to do this will result in rapid gas heater failure by sulfidation attack. The separate SO_2 circuit bypasses the gas heater.

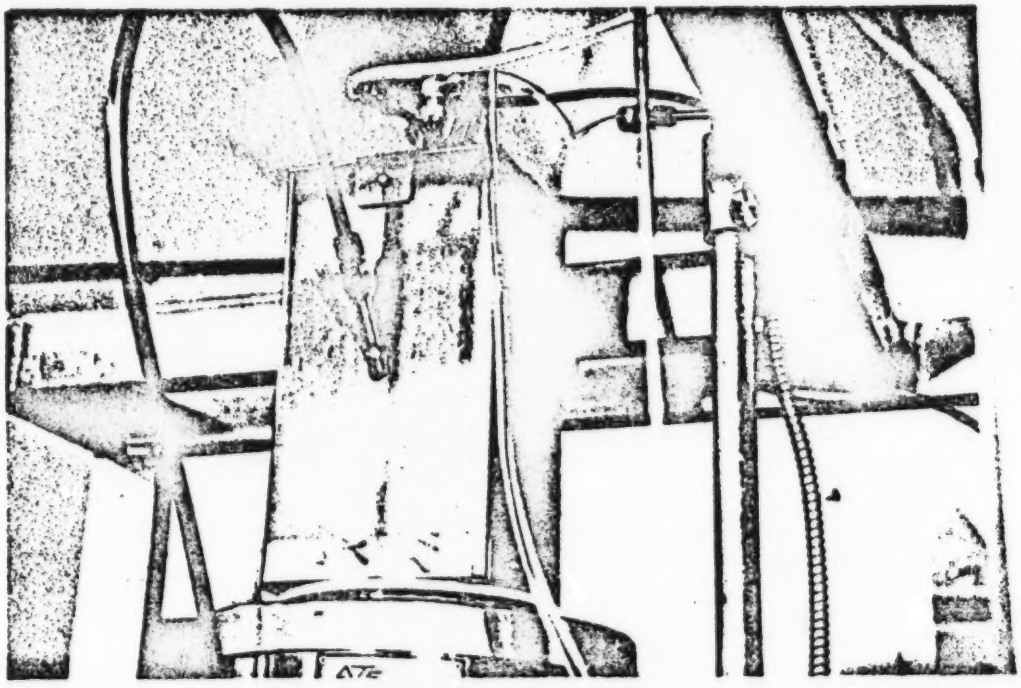
NOTE: All gas connections require 1/4 inch ID, 3/8 inch OD Tygon tube to fit the swagelock finger release fittings provided.

Figure 3 - Gas heater installation.

3a

gas heater

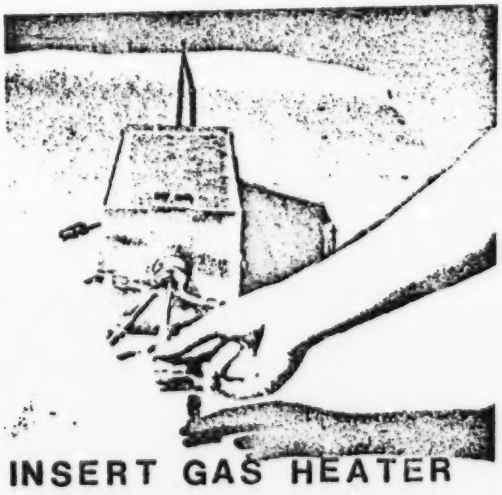
in position



3b

gas heater

removed



EXPERIMENTAL PROCEDURE

1. Place the program diskette ERODE in drive A of the IMB PC and close the drive door.
2. Turn on the computer, monitor screen and printer. If the computer was already on, reset the computer. (Press CTRL-ALT-DEL; see IBM User's Guide.) Ensure that there are at least 20 sheets of paper in the printer feed.
3. Enter the date at the computer's prompt in the format shown.
4. At the A prompt, type ERODE, Enter. The computer will load the control program erode. You will here a whirring noise from disc drive A, and the screen will display "operator ?:"
5. When "operator ?" appears, type in the operator's name or initials and press the Enter key. The screen will then ask for the time to be entered in the format hh:mm:ss.
6. The computer will now want to know the sample gas composition, and will display the following:

   Enter composition of test gas:

   nitrogen....%

   Type in the % composition of nitrogen and enter it. For example, for air, enter 79; it is not necessary to type the % sign. The computer will, in succession, request the percentage composition of oxygen, carbon dioxide, carbon monoxide, water vapour and sulfur dioxide. Enter the corresponding values.

7. The screen will now display:

   Enter description of sample

   #1:

   Type a description, up to 20 characters of sample 1, and enter it. The display will prompt successively for descriptions of samples 2, 3 and 4. Enter the information.

8. The screen will now display:

   Particle erodant type?

   Enter description, up to 20 characters, of the erodant.

9. The screen will prompt:

   Enter erode time per sample in minutes. Select the time based on your expeirmental requirements, and using the gas flows required to achieve the desired particle velocities, ensure that there is adequate gas available for the complete run.

10. The screen will prompt: General notes. You have up to 255 characters of general notes to type which will be displayed on the data log print-out for record keeping purposes.

11. The screen will display:

    INITIALIZATION COMPLETE: Please switch on the 220V.

    Switch on the 220 volt switch underneath the main control panel.

The screen will clear, and the inputted information will be stored.

A new display will appear, as shown in Figure 4. This is the control display which is used to set the experimental conditions of sample, temperature, gas flows, particle velocities, etc.

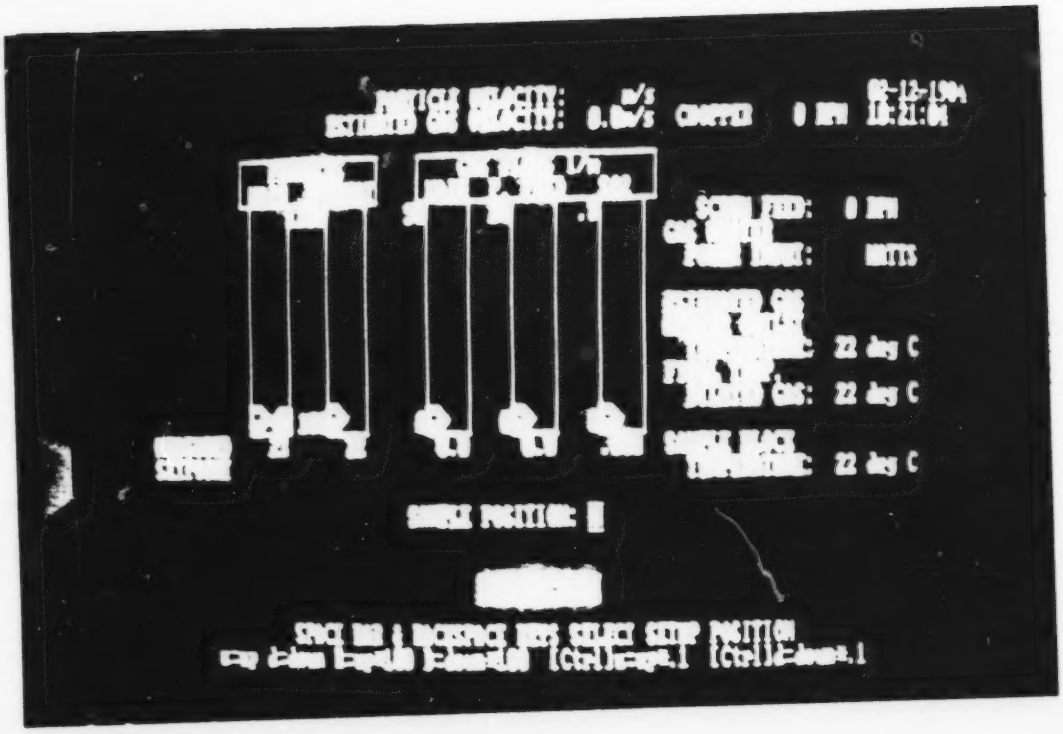
The operator must know the temperatures and gas flows required to achieve the desired particle velocities.

The operator must know the gas flows and powder feeder settings required to achieve the desired particle flow rate.

NOTE: The cursor in this display is a flashing box surrounding the variable to be changed. DO NOT TOUCH ANY KEYS UNLESS THE FLASHING CURSOR IS DISPLAYED.

1. The sample position meter will reset to position zero, and the cursor will appear at the bottom of the screen, surrounding sample position 0. This position is only used for velocity calibration. Press the U key on the keyboard once. This will move the temperature sample block, sample position 2, forward until it is under the gas-particle inlet. This is kept in this position during the initialization procedure to ensure that the desired sample temperature is attained.
2. Move the cursor to the next position by pressing the space key once. If you accidentally overshoot, move the cursor back with the backspace key. Note: if the sample position was 0 (zero), the cursor would move to the location chopper rpm at the top right of the screen, for velocity

Figure 4 - Control Display



measurement. With the sample holder in position 1, the cursor moves to the main furnace set point.

3. Set the main furnace set point to the desired value;

   To move up 10 degrees press u.

   To move down 10 degrees press d.

   To move up 100 degrees press U.

   To move down 100 degrees press D.

   To move up 1 degree press CTRL u.

   To move down 1 degree press CTRL d.

4. When the desired temperature is set, press the space bar again to move the cursor to the preheat furnace set point and set the preheat furnace temperature to the desired value in the same manner.

5. Move the cursor forward to the main gas flow set point. Do not try to set the flow unless the gas is on at a pressure of 10-15 psig. Set the main gas flow to the desired value by:

   Go up 0.5 l/min by pressing u.

   Go down 0.5 l/min by pressure d.

   Go up 5 l/min by pressing U.

   Go down 5 l/min by pressing D.

   Go up 0.05 l/min by pressing CTRL u.

   Go down 0.05 l/min by pressing CTRL d.

6. Move the cursor to the powder feeder gas monitor. NOTE: The standard CES erosion test facility does not include a control value on this gas flow. This can be fitted as an option. With the powder feeder fitted according to Sylco instructions, turn on the carrier gas at the regulator and manually set the flow to the desired value that will give the proper erodant mass flow rate in concert with the vibration amplitude and feed screw speed.
7. Move the cursor to the SO_2 setpoint and set the value desired as in step 5. Note all controls cause 1/100 the change that they did on the main gas setpoints.
8. Wait until the screen displays the message "Setpoints achieved, start experiment". Then, move the cursor to the position gas heater power input by pressing the space bar. The object of this control is to achieve a final dilute gas temperature as near as possible to the desired sample temperature. The temperature may be limited to a lower value by a safety circuit which protects the gas heater.

   Since the gas heater only heats the main gas flow, the flow from the particle feeder and the SO_2 circuit dilutes heated gas to a lower temperature.

   This is displayed as "final temperature diluted gas". The limitation arises because the outlet gas temperature of the gas heater cannot safely exceed 920°C.

   To set the temperature:

Press (small) u to go up 5 watts

Press (small) d to go down 5 watts

Press (capital) U to go up 50 watts

Press (capital) D to go down 50 watts

Increase the power input until either the desired final temperature diluted gas is reached, or limiting occurs. Higher temperatures may be achieved by reducing the dilution gas to main gas flow. If the gas flows or power setting combine to produce a potential overheat condition of the gas heater, the power level will automatically be reduced by 100 watts. Increase the power in smaller increments. This feature also will cut the power level if the main gas flow drops during an experimental run.

9. When the optimum gas temperature is achieved, in concert with the presence of the setpoints achieved display, move the cursor to sample position, and select position zero. At this point, the chopper rpm cursor location will appear in the upper right corner of the screen. Advance the cursor to this location by pressing space. Turn the chopper moter rpm on by pressing (U for up 100 rpm, u for up 10 rpm, D for down 100 rpm and d for down 10 rpm. Normally, set the motor speed to 500 rpm. Do not turn the motor on unless the water is flowing. Turn on the powder feeder, and adjust the feeder rpm to the rate desired. Note: for fine particles it may be necessary to use higher rpm's than and thus flowrates than desired to achieve a usable signal. This is a common

problem shared with the Ruff and Ives velocity technique. Wait until the displayed particle velocity stabilizes, which takes approximately 2 - 10 minutes depending on experimental conditions. Since the displayed velocity is the median of the measured velocities, it is a statistically determined velocity, and hence may vary by +(3 - 5)% when "stable". In a normal experimental run, the velocity measured will not be the actual particle velocity because the nozzle to sample distance is much larger than the nozzle to chopper disc distance, and deceleration of particles occurs over the increased distance. For closer measurement of velocities, install the supplied gas acceleration tube extension, which passes through the sample holder disc position zero hole DO NOT ALTER THE SAMPLE POSITION WITH THE EXTENSION IN PLACE. As supplied, the velocity measurement system is uncalibrated and may give a velocity measurement vs gas velocity valve that varies both by zero offset and slope from the actual relationship. Calibration is available by laser doppler velocimetry. Contact CES for details. Alternatively the user can replace the chopper disc and shaft assembly with his own Ruff and Ives assembly and calibrate against it.

10. When the desired velocity is obtained, move the sample disc to position 1, the temperature calibration block. Do not do so if the acceleration tube extension is in place. Wait until the displayed sample block temperature stabilizes. It will usually drop as the therm-

ocouple moves under the heated gas stream. Adjust the temperature by increasing the furnace temperatures and gas heater power levels within allowable limits;

T_{max} furnaces = 1100°C

T gas heater outlet Max = 900°C.

The process of steps 9 and 10 will be interactive since all variables are linked. Changing temperatures and power inputs will affect the particle velocity. Carefully record all settings used, as the data will be useful in determining desirable sample text conditions.

11. When the desired particle velocity and sample temperatures are achieved, and the Setpoints Achieved begin experiment prompt is displayed, make sure the sample holder is in position 1 and type "YES". This will not be displayed, but the computer will begin the experiment controlling the variables as inputted, and moving the samples at the time interval chosen. The operator must do the following during the experiment:

    1. Maintain the powder feeder flowrate at the desired setting by adjusting the pressure. As the amount of erodant in the canister decreases, the flow will increase.

    2. Ensure that there is adequate erodant in the powder feeder. If refilling is necessary, follow recommended Sylco procedures and carefully clean the "O"ring bearing surface with a fine brush before replacing the top.

    3. Monitor the screw feeder rpm, either on the screen or the print-

out. If it drops to zero, examine the Sylco drive to see if the screw has stopped turning. Note that the chain drive will still be moving because of the presence of a friction clutch in the dial. The powder feeder rpm needle gauge will not indicate a jammed screw as it measures motor rpm, not screw rpm. In the event of a jam, invert the feeder and turn the speed to the highest level. If this works, only the sample under the gas particle stream at the time of the jam will be affected and the run may be continued. If not, abort the run [turn off 220V, turn off computer] and clean the feeder following Sylco instruction.

SYLCO POWDER FEEDER FLOW RATE CALIBRATION.

Construct a glass tube about 5 cm diameter x 40 cm long, with a removable plug in one end, holding a 1/4" metal tube strip. Cover the other end with a wire mesh finer than the finest particle size to be used. See figure 5.

Connect the 1/4" I.D x 3/8" O.D. tygon tubing, and put a short coupling [3 cm long] of 3/8" I.D. tygon on the end of this.

Weigh the assembly to +.01 grams on a balance;

Start the screw feeder, at a given flow rate and vibration amplitude. After approximately 1 minute to allow equilibration insert the outlet line of the feeder into the 3/8" tygon, recording the time. Allow the flow to continue for 5 minutes, disconnect and reweigh the tube assembly.

Repeat this procedure for screw feeder rpm's of 0, 100, 200, 300, 400, and maximum, calculate the feed rates in g/min and plot the date. Figure 6 gives some representative data; further data is available from Sylco, and some is included with the Sylco literature.

Figure 5 - Powder feeder calibration tube.

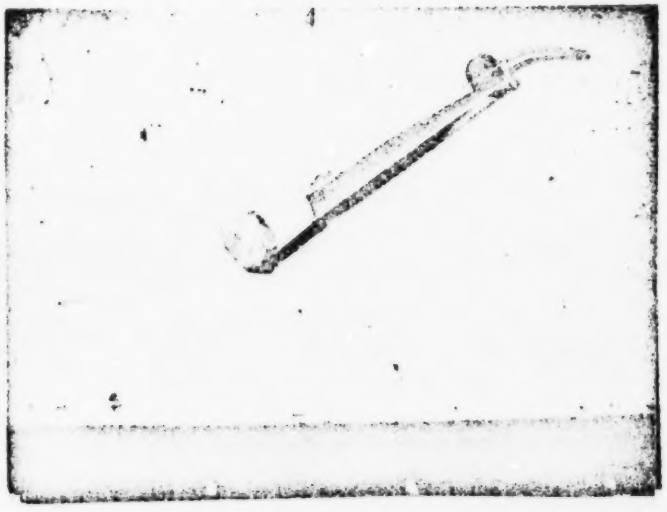
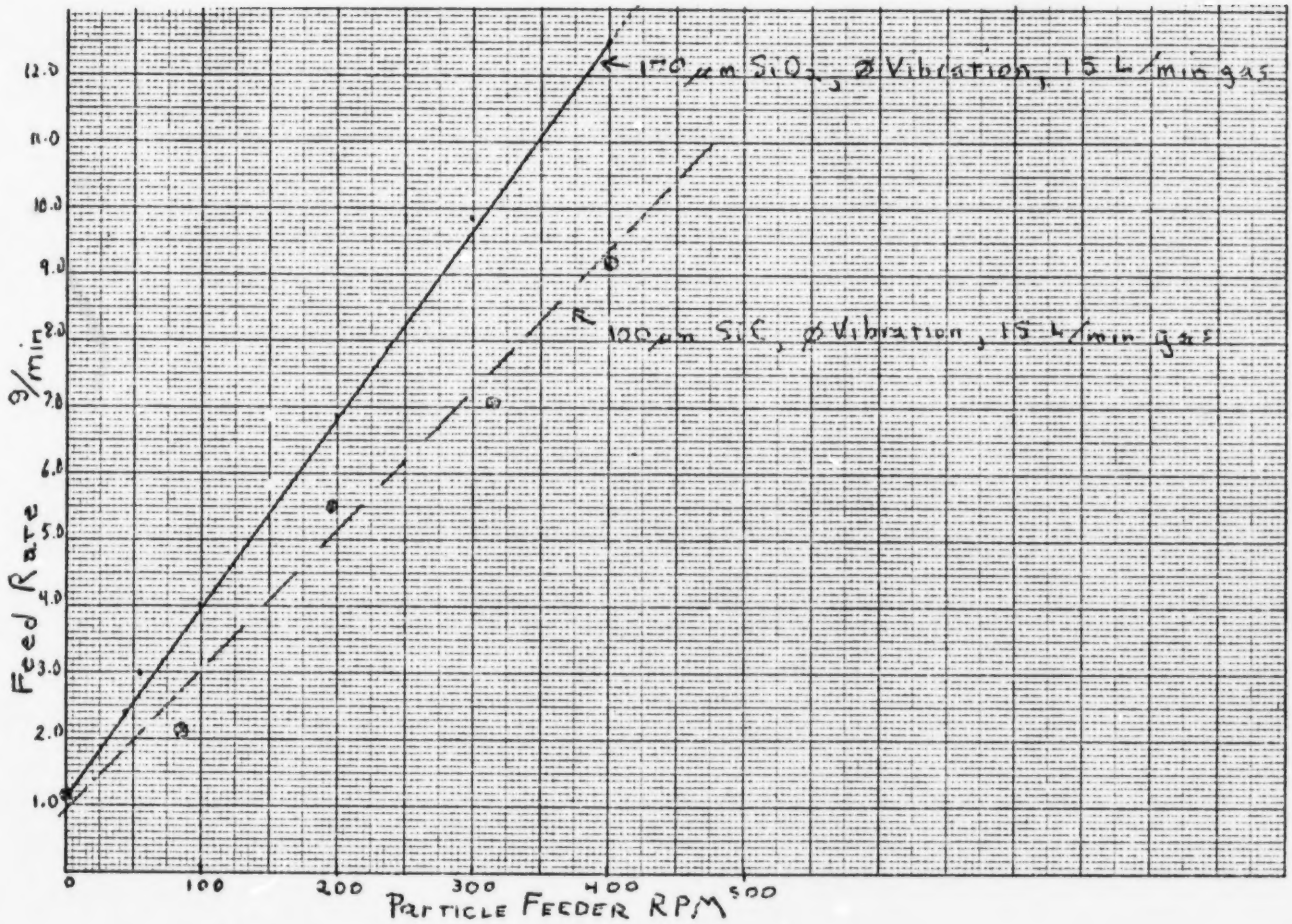


Figure 6 - Powder feeder calibration curves

Representative data for 170μm silica and 100μm SiC.



THEORY OF OPERATION

Although a large number of components are involved the CES erosion test rig is designed to provide what is basically a hot "sandblast" test chamber for materials samples. It controls and measures the sample temperature, gas flow rates and particle velocity, and particle feed rate.

Particles of erodant are fed from a commercial powder feeder at controlled flow rates into a carrier gas stream. They are carried to a mixing chamber where heated, accurately flow controlled gas is added, along with small amounts of corrosive gas. The gas particle stream exits through an acceleration orifice, as shown in Figure 7.

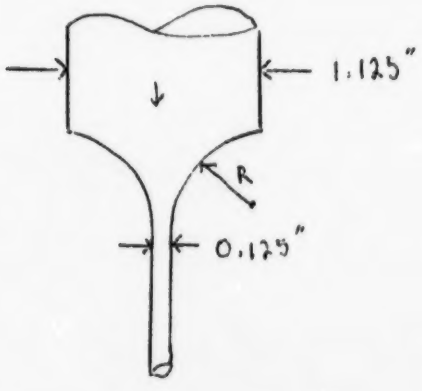


Fig. 7 - Acceleration Orifice.

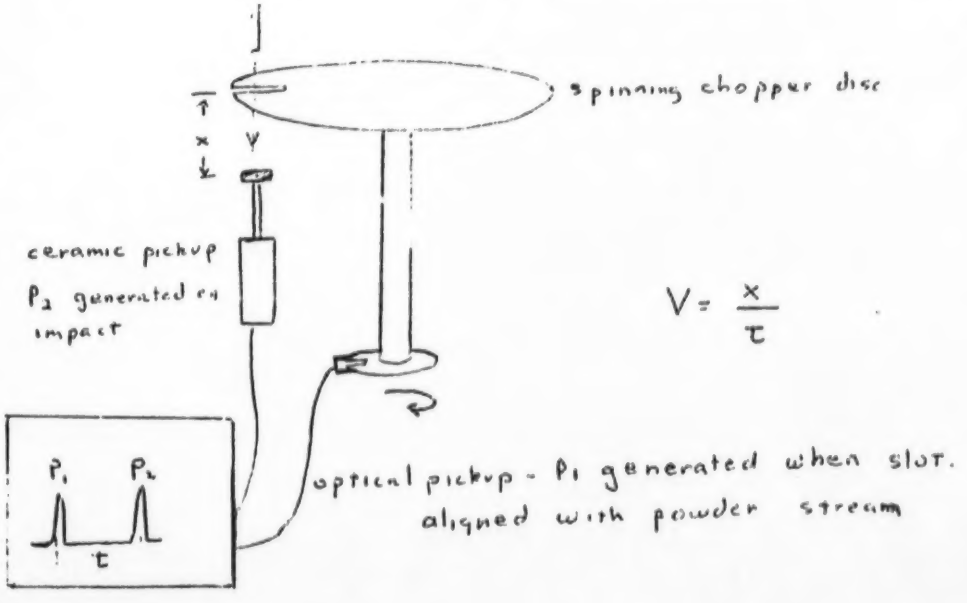
The accelerated gas passes along a 1 meter long x 6 mm diameter composite stainless steel tube through a furnace. This furnace acts as heated insulation to keep the gases warm. The tube passes into a large furnace containing the samples and temperature and velocity measurement devices.

The sample holder position is computer controlled. Various impact angles [0° - 90°in 15° steps] cab be set manually by the operator. The operator must ascertain that the sample is centred under the particle inlet tube. All other functions are largely computer controlled.

The sample temperature is measured by placing a sample holder with embedded thermocouple under the gas particle stream.

Particle velocity is measured by an electronic variation on the Ruff and Ives 2 disc technique as shown in Figure 8.

Figure 8 - Particle Velocity Measurements



The actual chopper disc geometry is different, however the measurement principal is the same as given here.

The particles impinge on the rotating disc. When the slot is under the jet, particles can travel through the plane of the disc. At this point, an optical pickup sends a time pulse to the computer. When the particles hit the ceramic piezoelectric sensor, a second time pulse is generated. From the chopper disc to sensor distance and the measured time interval the velocity is calculated. A running median velocity is calculated and displayed on the computer screen.

Major Components and Suppliers

1) Furnaces

main furnace - ATS 3210 split furnace

gas heater furnace - ATS 3110 tube furnace

Supplier

Intertechnology Ltd.

3869 Boulevard des Sources

Dollard des Ormeaux, Quebec

H9B 2AZ

2) Gas glow meters and valves

main flow meter - transducer 8663-0454 0-50 lpm

valve 8241-0454 1-50 lpm

SO_2 flow meter - transducer valve 8141-0452 0-0.5 lpm

valve 8241-0452 0.01-0.5lpm

particle feeder flow meter - transducer 8148-0424 0-20 lpm

Supplier

Matheson

P.O. Box 89

530 Watson Street, E.

3) Gas heater

SCH114372A series 1. Whitby, Ont. L1N 5R9

serpentine heater

Supplier

ECG Canada Inc.

8580 Darnley Road

Montreal,PQ

H4T 1N6

4) Computer

IBM PC with 2 x 160k disc drives

Epson MX-80 printer

Tecmar Data Acquistion Board

Supplier

Computerland

5) Powder Feeder

Sylco Mark IX

Supplier

Sylvester and Co.

24700 Highpoint Road

Beachwood, Ohio

44122

6) Electronics Interface

Various components

Supplier

Electrosonic

1100 Gordon Baker Road

Willowdale, Ontario

M2H 3B3

Future Electronics

230 Hymus Blvd.

Pt. Clair, Quebec

Service:

Centre for Energy Studies
Technical University of Nova Scotia
contact: Mr. G. Park or Mr. G. S. Trivett

THEORY OF OPERATION, CONTROL SYSTEM INTERFACE

Introduction:

The function of the control system interface can be subdivided into data acquisition and control functions. In general, data from various sensors is converted to digital form and fed to the IBM-PC, where the control program uses the information to make adjustments and decisions concerning control functions. The results are fed back to the interface, which outputs both analog and digital control signals to gas valves, solid state relays, motor controller, etc. All analog and digital communications between the IBM-PC and the control system interface are made through a TECMAR-Lab Master Data Acquisition Sub-system. See TECMAR manual for details.

Data acquired is as follows:

I) Thermocouples:

1) T.C. 1 - This is the main furnace temperature control thermocouple. Input is to analog channel 0.

2) T.C.2 - This is the acceleration tube pre-heat furnace temperature control thermocouple. Input is to analog channel 1.

3) T. C. 3 - This is the sample block thermocouple mounted in the sample holder at position 1. Input is to analog channel 2.

II) Matheson Gas Flow Meters:

1) Gas Flow 1 - This is the main gas flow to the gas heater. The range is 0 - 50 lpm. Input is to analog channel 3.

2) Gas Flow 2 - This is the powder feeder gas flow. The range is 0 - 20 lpm. Sensor is mounted inside the powder feeder housing. Input is to analog channel 4.

3) Gas Flow 3 - This is the SO_2 flow meter. The range is 0 - .5 lpm. Input is to analog channel 5.

III) Cold Junction Compensation:

An Analog Devices AD590 linear temperature sensor is mounted in one of the mounting holes of the thermocouple terminal block. This device puts out a current proportional to Kelvin temperature $\approx$1V/°K. A 1K trimmer in parallel with an 120 ohm fixed resistor on the main P.C.B. converts this input to mV and can be adjusted for accurate room temperature indication. Input is to analog channel 15.

IV) Gas Heater Power Input Sense Circuit:

Power to the gas heater is controlled by a pulse-width modulated triac and therefore current and voltage are non-sinusoidal waveforms. Furthermore the gas heater temperature and hence the winding resistance is dependent on

both power input and gas flow.

To accurately measure power input to the gas heater, both the RMS current and RMS voltage are measured.

Two 30:1 toroidal current transformers in cascade sense the gas heater input current. The output of the second transformer is fed to an op-amp current to voltage converter. A second op-amp provides AC gain and the correct input level for an Analog Devices AD536 true RMS to DC converter. A 220V primary step down transformer senses the voltage across the gas heater element. An adjustable voltage divider reduces the output to a suitable level for a second AD536. (See Fig. 2) The computer reads current on analog channel 6, voltage on channel 7.

V) Particle Velocity Sensor Signal Conditioning Sub-system:

There are two inputs to this circuit: A low level analog signal from the piezo-electric ceramic impact sensor and a digital signal from the chopper's optical switch. The analog signal is amplified by three op-amps in a variable gain differential input configuration (refer to the upper block, Fig. 1). Two CMOS gates and a diode provide further amplication, filtering and level clipping.

The output of the optical switch is conditioned by an NPN signal transistor (which also drives the "chopper" indicator LED) and an inverter connected CMOS NAND gate.

Two more NAND gates form a set-reset flip-flop. A negative input from the chopper optical switch (indicating main chopper closed) sets the flip-flop. The first particle impact after the chopper has opened resets the flip-flop to its other state. Two outputs are produced by this circuit: output one to J1 pin 8 is the chopper optical switch signal and is used for RPM measurement only. Output two to J1 pin 6 is the logical AND of chopper open and flip-flop set. The result is a pulse width equal to the time of flight between chopper and sensor. If no particles are detected the pulse width is equal to .25 x 60/RPM chopper. This condition is detected by software. (see Control Program documentation) Pulse width measurements are performed by the AM9513 programmable timer on the TECMAR Labmaster board. Chopper RPM input is to counter #3 gate. Pulse width input is to counter #4 gate.

VI) Screw Feed RPM

A black and white plastic collar has been pushed over the slip clutch coupling that drives the Sylco powder feeder's auger. This allows the auger rpm to be measured by a reflective optical pickup. See Fig. 3 for circuit details. Input is to counter #2 of the TECMAR Labmaster AM9513 programmable

timer.

VII) Sample Position:

An optical switch detects index holes in a brass disc mounted to the upper end of the sample holder shaft. Two limit switches prevent 360° rotation and enable the control program to find position zero by reversing for 30 seconds. The optical switch output goes to pin 17 of J3 which is pin one of port A of the TECMAR Labmaster's 8255 parallel I/O device.

Parameters controlled are as follows:

I) Furnaces:

1) Furnace 1 - This is the main sample furnace. The two elements in this split furnace are controlled by two 220V, 45A solid state relays. Output from port B, bit 3 of the 8255 PIA on the TECMAR Labmaster mother board (J3, pin 24) drives both relays in parallel through a 2N2222 switching transistor.

2) Furnace 2 - This is the Acceleration tube Pre-heat furnace. Output from port B, bit 4 of the 8255 PIA (J3, pin 11) buffered by a 2N2222, controls a 220V, 25A solid state relay.

II) Gas Heater:

Counter #5 of the AM9513 programmable timer I.C. on the TECMAR Labmaster mother board is programmed as a variable pulse width mono-stable. The counter is triggered on the zero-crossing of the 220V supply by a trigger circuit consisting of a bridge rectifier, 6V Zener limitter, an opto-isolator and 2N2222 switching transistor.

A software determined time later (.05 to 16.65 ms) the counter produces a trigger pulse. This triggers the MOC3011 opto-isolator-triac driver at U5 which triggers triac Q_{14}. Q_{14} triggers the high current triac through a capacitive network designed to produce an initial high trigger current, followed by a low maintenance current to minimize power dissipation in Q_{14}.

III) Sample Positioning Motor:

A reversible gear motor with chain drive is used to position the sample holder disc. Bits four and six of the Labmaster 8255, port B trigger the forward and reverse solid state relays, respectively.

IV) Chopper Speed Control:

The TECMAR Labmaster Digital to Analog Converter output No. 2 (DAC 2) drives the Ultracon JC017 SCR motor controller which controls the

MO17 DC motor. A sealed optical isolator module isolates the computer and interface circuitry from the JCO17 circuit. See the Ultracon Manual for wiring details.

V) Gas Valves:

The Matheson control valves operate in a proportional region between approximately 10 and 20 volts. Furthermore, the TECMAR interface provides only two DAC outputs, one of which is dedicated to the Ultracon controller. The circuit comprised of U1, Q2 through Q9 and four CMOS inverters, performs the functions of multiplexing the single 0-5V output of DAC 1 into four analog outputs and level shifting to the 0-20V range. The MC14529 at U1 is a dual four channel analog multiplexer, both sections of which are controlled in tandem by common select lines (pins 6,7 U1). Each of the four CMOS inverters, and its associated NPN and PNP transistors forms an inverting analog amplifier. When a channel is selected by the MC14529 then R11, R12 and the voltage divider formed by, eg. R21, R22, create a negative feedback loop with a gain of (470K/470K)(3K9 + 1K)/1K = 4.9. When a given channel is not selected, a 100n capacitor holds the previous voltage for up to several seconds. This is possible because of the high input impedence of CMOS devices.

Corrosion - Erosion tester

Control System

Last Mod. Feb 12 '84

G. Park

Piezoelectric Vibration Sensor

Signal Conditioning P.C.B.

G.E. quarte gas heater

Acc. Tube furnace

Main furnace

117 VAC.

Main flow

Flow 0-50lpm

Flow 0-3lpm

Flow 0-20lpm

Powder Feeder

T.C.s Type K

Main furnace

Pre-heat

Sample block

AD590

Forward SSR

Reverse SSR

MC14529

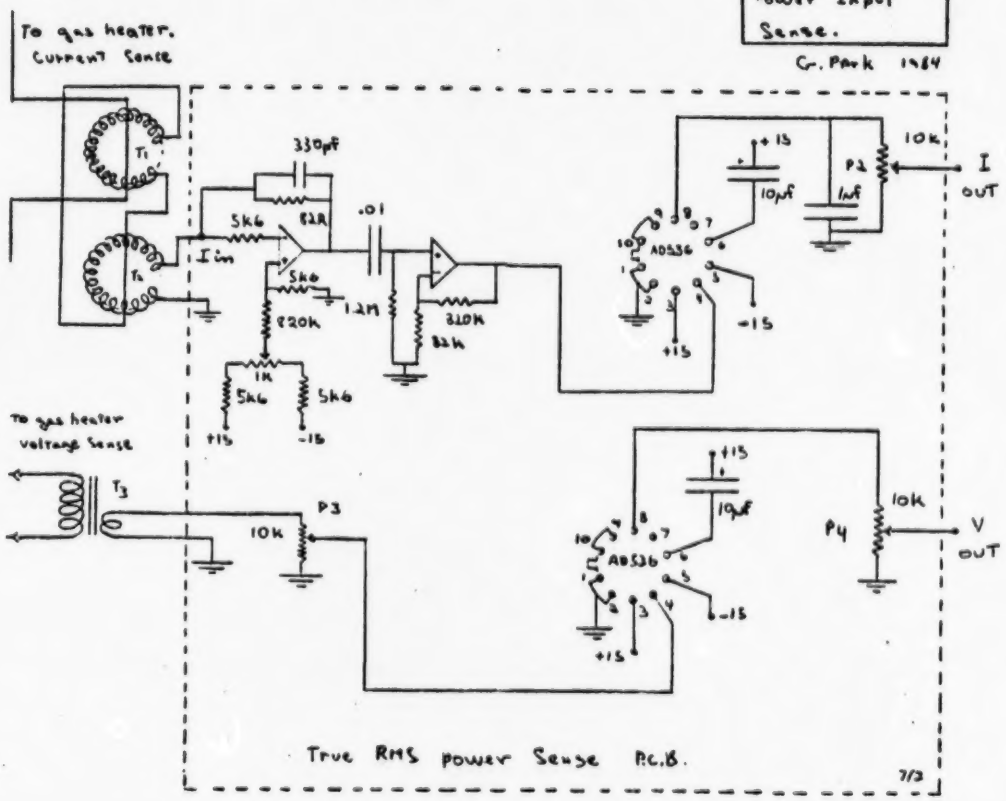
Mac 3011

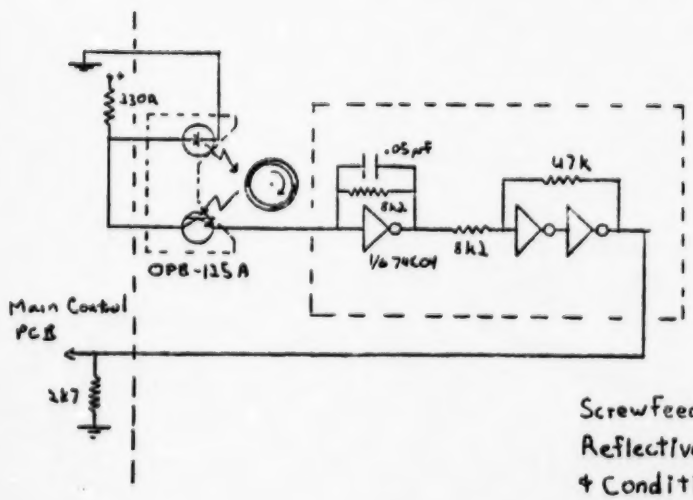
Main Control P.C.B.

Corrosion-Erosion Test Rig

True RMS to D.C. conversion for Gas heater Power Input Sense.

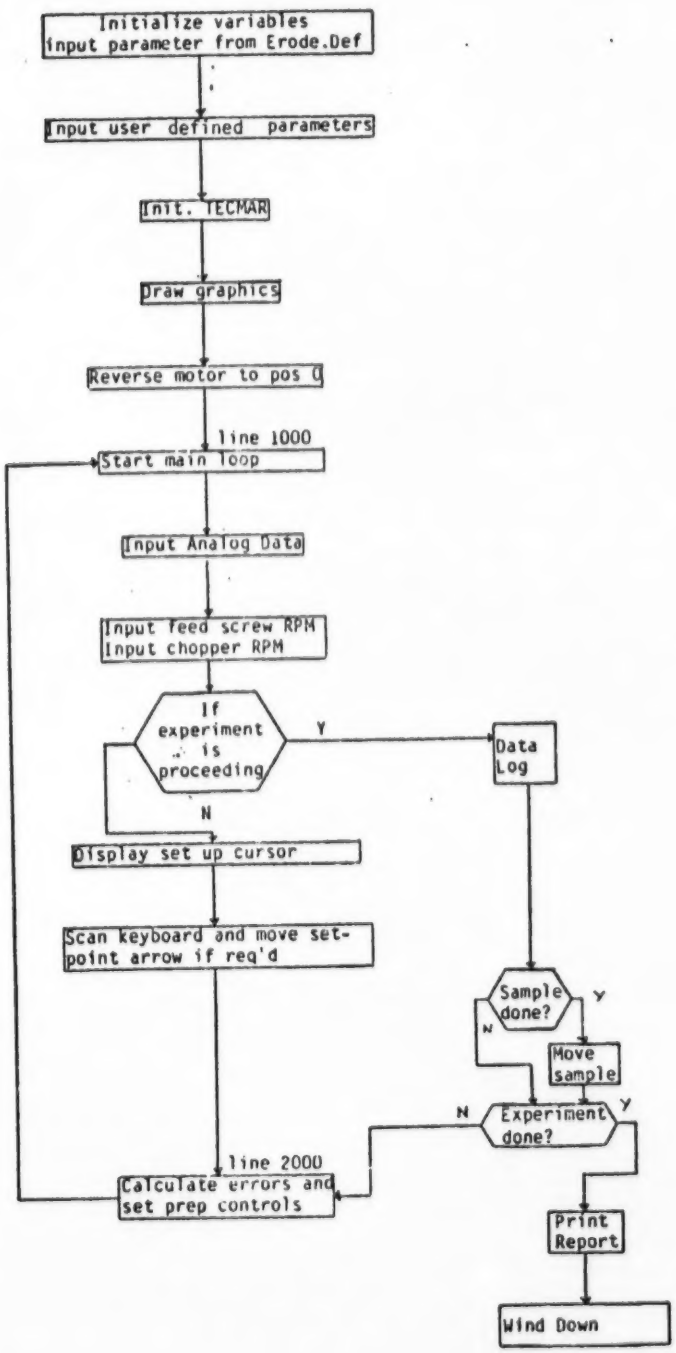
Gr. Park 1984





Screw Feed RPM Reflective Pickup & Conditioning Circuit.

CONTROL PROGRAM FLOWCHART



```
1 REM HIGH TEMPERATURE CORROSION EROSION TEST RIG CONTROL PROGRAM
2 REM
  REM       Author.....Geoff Park.....
  REM Copyright 1983 (c)  The Centre for Energy Studies,
5 REM                     box 1000, Halifax, N.S.,Canada.
  REM                     last modified, 28 FEB 84
10 SCREEN 2:KEY OFF
20 ON ERROR GOTO 40900
100 REM definitions
105 DIM GCOMP(6),CPGTOT(4),SDISCR$(10),CESHEAD$(3)
106 DIM MPTR(20),SPTR(20),BLANK(20),BLOK(50)
110 DEF FNHI(X)=INT(X/256)
120 DEF FNLO(X)=X-FNHI(X)*256
121 REM cp of gas mixture in j/l stp
122 DEF FNCP(T)=(CPGTOT(1)+CPGTOT(2)*T+CPGTOT(3)*T*T+CPGTOT(4)*T*T*T)/22.4
130 LINV=220*1.414:GHR=40:PI=3.14159:REM line voltage, gasheater resistance
135 NOZA=.0000367:REM nozzle area in m2
140 FF$=CHR$(12):LF$=CHR$(10):REM form feed and line feed
150 OPEN "i",#1,"erode.def"
160 INPUT#1, NOZA:REM nozzle area
165 INPUT #1,SCANRAT:REM scan rate for data log
170 INPUT #1,PBAND1,PBAND2:REM preportional band for furnace controls
175 INPUT #1,GVCONR1,GVCONR2,GVCONR3:REM INTEGRATION RATES FOR GAS VALVE CONTR
180 INPUT #1,RPMCONR:REM INTEGRATION RATE FOR CHOPPER RPM
185 INPUT #1,FASPD,SLOSPD%:FASPDM=FASPD/60
187 INPUT #1,RGHWCON
188 INPUT #1,SKIP
189 INPUT #1,DIST
190 INPUT #1,PVMEDR:REM particle velocity median rate constant
192 CLOSE #1
200 REM initialization
220 ST%=128:REM toggle flag for safety shutoff
221 BS$=CHR$(8)
230 REM data for cp of gases
240 DATA 29.0,.2199e-2,.5723e-5,-2.871e-9:REM nitrogen
250 DATA 29.1,1.158e-2,-.6076e-5,1.311e-9:REM oxygen
260 DATA 36.11,4.233e-2,2.887e-5,7.464e-9:REM carbon dioxide
270 DATA 28.95,.411e-2,.3548e-5,-2.22e-9:REM carbon monoxide
280 DATA 33.46,.688e-2,.7604e-5,-3.593e-9:REM water vapor
290 DATA 38.91,3.904e-2,-3.104e-5,8.606e-9:REM sulfer dioxide
300 CLS
303 INPUT "    Operator ";OPNAM$
305 LOCATE 2:INPUT "Please enter the current time (HH:MM:SS)  ",T$
307 IF (MID$(T$,3,1)<>":") OR (MID$(T$,6,1)<>":") OR LEN(T$)<>8 THEN 305
308 TIME$=T$
310 LOCATE 5
320 PRINT "enter composition of test gas:"
330 INPUT "          nitrogen....% ",GCOMP(1)
340 INPUT "            oxygen....% ",GCOMP(2)
350 INPUT "    carbon dioxide....% ",GCOMP(3)
360 INPUT "  carbon monoxide....% ",GCOMP(4)
370 INPUT "       water vapor....% ",GCOMP(5)
380 INPUT "    sulfur dioxide....% ",GCOMP(6)
385 SUM=0:FOR J=1 TO 6:SUM=SUM+GCOMP(I):NEXT I
390 IF INT(SUM*10) <>1000 THEN PRINT "     sum not 100%":GOTO 310
395 PRINT "                          "
400 FOR J=1 TO 6
410 FOR I=1 TO 4:READ CPG:CPGTOT(I)=CPGTOT(I)+CPG*GCOMP(J)/100:NEXT I
420 NEXT J
450 LOCATE 5,40:PRINT "Enter Description of sample"
460 FOR SN=1 TO 4
470 ROW=SN+6
480 LOCATE ROW,40:PRINT "#";SN;": ";
```

```
500 NEXT SN
505 LOCATE 12,40:PRINT "Particle erodant type? :"
506 LOCATE 13,40:LINE INPUT "    : ",SDISCR$(9)
510 LOCATE 15,10:INPUT "Enter erode time per sample in minutes ",TMPERSM
520 LOCATE 20,10:LINE INPUT "General notes: ",SDISCR$(10)
590 GOSUB 9000:REM init tecmar
595 PRINT "":PRINT "      INITIALIZATION COMPLETE: Please switch on the 220
olt mains ."
596 LINE INPUT "                                hit return key when ready";DUMMY$
600 CLS:GOSUB 5000:REM draw & setup display graphics
910 REM reverse motor to pos zero
912 OUT TPPB%,PBDAT% OR &H40
914 GOSUB 50000:STRTM=TIMIN
916 GOSUB 50000:IF TIMIN<STRTM+.5 THEN PLAY "O0132C":GOTO 916
918 OUT TPPB%,PBDAT% AND &H0F
920 INC=1:GOSUB 40680
990 NSP%=1:REM on screen setup pointer
1000 REM main loop
1005 REM input data
1006 LINE(X1,Y1)-(X2,Y2),0,B
1010 GOSUB 20100:REM t.c. #1 main furnace
1020 GOSUB 20200:REM t.c. #2 preheat furnace
1030 GOSUB 20300:REM t.c. #3 sample block
1040 GOSUB 10100:REM gas meter #1 main flow
1050 GOSUB 10200:REM gas meter #2 particle feeder
1060 GOSUB 10300:REM gas meter #3 SO2 flow
1063 GOSUB 10400:REM read gas heater power input
1065 TOTFLO=GASFLO1+GASFLO2+GASFLO3
1068 GOSUB 3100
1070 GOSUB 30000:REM read rpm of feed screw
1080 GOSUB 30100:REM read chopper rpm
1085 IF(SAMPOS%=0) AND (RPMSET>50) THEN GOSUB 30200
1090 IF(EXPROC) THEN 1800:REM if experiment is under way
1100 REM change setpoints:
1105 GOSUB 40500
1110 Q$=INKEY$:IF Q$=" " THEN NSP%=NSP%+1
1112 COMM$=COMM$+Q$:COMM$=RIGHT$(COMM$,3)
1115 IF Q$=BS$ THEN NSP%=NSP%-1
1118 INC=0
1120 IF Q$="u" THEN INC=1
1122 IF Q$="U" THEN INC=10
1123 IF(Q$<>"") THEN IF ASC(Q$)=21 THEN INC=.1
1124 IF Q$="d" THEN INC=-1
1128 IF Q$="D" THEN INC=-10
1129 IF(Q$<>"") THEN IF ASC(Q$)=4 THEN INC=-.1
1130 IF NSP% > 8 THEN NSP%=8
1131 IF NSP%<1 THEN NSP%=1
1135 ON NSP% GOSUB 1150,1170,1200,1250,1300,1350,1400,1450
1136 LINE(X1,Y1)-(X2,Y2),1,B
1140 IF((ABS(TSET1-TC1)<10) AND (ABS(TSET2-TC2)<10) AND (ABS(GASET1-GASFLO1)<1
AND (ABS(GASET2-GASFLO2)<1) AND (ABS(GASET3-GASFLO3)<.015)) THEN 1145 ELSE 189
1145 LOCATE 20,27:PRINT "SETPOINTS ACHIEVED....begin experiment?":SA%=1
1147 IF COMM$="YES" OR COMM$="yes" THEN EXPROC=1:PFRPMN=RPM2:PFRPMX=RPM2:LINE(
Y1)-(X2,Y2),0,B:GOSUB 6000
1148 GOTO 2000
1150 LOCATE 19,44,0:SAMPOS%=SAMPOS%+INC:PRINT USING "##";SAMPOS%:IF((SAMPOS%<0
OR (SAMPOS%>5)) THEN SAMPOS%=5
1153 X1=350:Y1=143:X2=360:Y2=152
1155 LOCATE 3,53,0:IF SAMPOS%<>0 THEN PRINT "                    "
1156 GOSUB 40600:RETURN
1170 IF(SAMPOS%<>0 AND Q$=" ") THEN NSP%=NSP%+1:RETURN
1171 IF(SAMPOS%<>0 AND Q$=BS$) THEN NSP%=NSP%-1:RETURN
1175 LOCATE 3,53,0:PRINT USING " SPEED  #### SET";RPMSET:RPMSET=RPMSET+10*INC
1176 X1=480:Y1=24:X2=512:Y2=15
1177 IF RPMSET<0 THEN RPMSET=0:RPMCON=0
1180 RETURN
1200 LOCATE 17,12,0:PRINT USING "####";TSET1:TSET1=TSET1+10*INC
```

```
1180 RETURN
1200 LOCATE 17,12,0:PRINT USING "####";TSET1:TSET1=TSET1+10*INC
1205 X1=88:Y1=136:X2=120:Y2=127
1210 IF TSET1>1120 THEN TSET1=1120
1212 IF TSET1<0 THEN TSET1=0
1215 PUT(104,YPS1),BLANK,AND:YPS1=110-TSET1/16:PUT(104,YPS1),SPTR,OR
1220 RETURN
1250 LOCATE 17,20,0:PRINT USING "####";TSET2:TSET2=TSET2+10*INC
1255 X1=152:Y1=136:X2=184:Y2=127
1260 IF TSET2>1120 THEN TSET2=1120
1262 IF TSET2<0 THEN TSET2=0
1265 PUT(168,YPS2),BLANK,AND:YPS2=110-TSET2/16:PUT(168,YPS2),SPTR,OR
1270 RETURN
1300 LOCATE 17,30,0:PRINT USING "##.#";GASET1:GASET1=GASET1+.5*INC:IF GASET1<0
HEN GASET1=0
1305 X1=232:Y1=136:X2=264:Y2=127
1307 IF GASET1>10 THEN X1=230
1310 IF GASET1>50 THEN GASET1=50
1315 PUT(248,YPS3),BLANK,AND:YPS3=110-GASET1*1.4:PUT(248,YPS3),SPTR,OR
1320 RETURN
1350 LOCATE 17,38,0:PRINT USING "##.#";GASET2:REM disable GASET2=GASET2+.2*INC
F GASET2<0 THEN GASET2=0
1355 X1=296:Y1=136:X2=328:Y2=127
1357 IF GASET2>10 THEN X1=294
1360 IF GASET2>20 THEN GASET2=20
1365 PUT(312,YPS4),BLANK,AND:YPS4=110-GASET2*3.5:PUT(312,YPS4),SPTR,OR
1370 RETURN
1400 LOCATE 17,46,0:PRINT USING ".###";GASET3:GASET3=GASET3+.005*INC:IF GASET3
 THEN GASET3=0
1405 X1=360:Y1=136:X2=392:Y2=127
1410 IF GASET3>.5 THEN GASET3=.5
1415 PUT(376,YPS5),BLANK,AND:YPS5=110-GASET3*140
1416 PUT(376,YPS5),SPTR,OR
1420 RETURN
1450 LOCATE 8,66,0:PRINT USING "####";GHWSET:GHWSET=GHWSET+INC*5:IF GHWSET<0 TH
N GHWSET=0
1455 X1=520:Y1=64:X2=552:Y2=55
1460 IF GHWSET>1500 THEN GHWSET=1500
1490 RETURN
1800 GOSUB 50000
1820 IF EXPTM>SCANRAT*SCANS% THEN GOSUB 60500:SCANS%=SCANS%+1
1830 IF EXPTM>4*TMPERSM THEN 55000
1840 IF EXPTM>(SAMPOS%-1)*TMPERSM THEN INC=1:GOSUB 1150:LPRINT TAB(30);"SAMPLE
";SAMPOS%-1
1890 LOCATE 20,27:IF SA%=1 THEN SA%=0:PRINT "
    "
2000 REM controls
2002 GOSUB 40500
2005 REM gas valves
2010 GVCON1=(GASET1-GASFLO1)*GVCONR1+GVCON1:IF GVCON1>4.9 THEN GVCON1=4.9
2020 IF GVCON1<0 THEN GVCON1=0
2030 GVCHAN%=1:GOSUB 40000:DAC1V=GVCON1:GOSUB 30400:REM gas valve 1
2035 GASET2=GASFLO2:REM manual control on this one
2040 GVCON2=(GASET2-GASFLO2)*GVCONR2+GVCON2:IF GVCON2>4.9 THEN GVCON2=4.9
2050 IF GVCON2<0 THEN GVCON2=0
2060 GVCHAN%=2:GOSUB 40000:DAC1V=GVCON2:GOSUB 30400:REM gas valve 2
2070 GVCON3=(GASET3-GASFLO3)*GVCONR3+GVCON3:IF GVCON3>4.9 THEN GVCON3=4.9
2080 IF GVCON3<0 THEN GVCON3=0
2090 GVCHAN%=3:GOSUB 40000:DAC1V=GVCON3:GOSUB 30400:REM gas valve 3
2092 GHWCON=(GHWSET-GHW)*RGHWCON+GHWCON:IF GHWCON>100 THEN GHWCON=100
2093 IF GHWCON<0 THEN GHWCON=0
2094 PW%=430-GHWCON*4:GOSUB 30300
2100 REM furnaces
2110 MKSP%=MKSP%+1:IF MKSP%>10 THEN MKSP%=0
2120 TFDIF1=(TSET1-TC1)/PBAND1
2130 TFDIF2=(TSET2-TC2)/PBAND2
```

```
2150 IF(TFDIF2 > MXSP%) THEN GOSUB 40210 ELSE GOSUB 40400
2155 GOSUB 40500
2160 REM rpm of chopper
2170 RPMCON=(RPMSET-RPM3)*RPMCONR+RPMCON
2180 IF RPMCON > 4.9 THEN RPMCON=4.9
2190 IF RPMCON<0 THEN RPMCON=0
2195 IF SAMPOS%<>0 THEN RPMCON=0
2200 DAC2V=RPMCON:GOSUB 30500:REM dac #2 out
2210 GOTO 1000
3100 REM calculate estimated gas temps:
3105 IF GHWSET<=0  OR TOTFLO<1  THEN GHWSET=0:TGHOUT=ROOMT:TGAS=ROOMT:GOTO 315
3110 JPLGHO=GHWSET*60/GASFLO1
3120 FOR IT=1 TO 5:TGHOUT=JPLGHO/FNCP(TGHOUT):NEXT IT
3122 TGHOUT=TGHOUT+ROOMT
3130 JPLDIL=JPLGHO*GASFLO1/TOTFLO
3140 FOR IT=1 TO 5:TGAS=JPLDIL/FNCP(TGAS):NEXT IT
3142 TGAS=TGAS+ROOMT
3150 RTK=ROOMT+273.15
3160 TGASK=TGAS+273.15
3170 HOTFLO=TOTFLO*TGASK/RTK
3175 IF TGHOUT>920 THEN GHWSET=GHWSET-100:LOCATE 8,66,0:PRINT USING "####";GHW
T
3180 HGASV=HOTFLO/(60000!*NOZA):REM gas vel m/s
3185 LOCATE 2,43,0:PRINT USING "###.#";HGASV
3187 LOCATE 12,66,0:PRINT USING "####";TGHOUT
3189 LOCATE 14,66,0:PRINT USING "####";TGAS
3190 RETURN
5000 REM draw and setup display graphics
5006 GET(0,8)-(15,0),BLANK:LOCATE 1,1,0:PRINT" m s"
5007 GET(7,8)-(15,0),MPTR:GET(23,8)-(31,0),SPTR
5008 LOCATE 1,1,0:PRINT "      "
5010 LOCATE 19,28,0:PRINT"SAMPLE POSITION:"
5020 LOCATE 1,25,0:PRINT"PARTICLE VELOCITY:"
5030 LOCATE 1,48,0:PRINT"m/s"
5040 LOCATE 1,71,0:PRINT DATE$
5050 LOCATE 2,20,0:PRINT"ESTIMATED GAS VELOCITY:"
5060 LOCATE 2,48,0:PRINT"m/s"
5070 LOCATE 4,14,0:PRINT"FURNACES"
5080 LOCATE 4,33,0:PRINT"GAS FLOWS l/m"
5090 LOCATE 5,12,0:PRINT"MAIN  PREHEAT"
5100 LOCATE 5,30,0:PRINT"MAIN  P. FEED   SO2"
5110 LOCATE 6,16,0:PRINT"1200"
5120 LOCATE 6,28,0:PRINT"50"
5130 LOCATE 6,36,0:PRINT"20"
5140 LOCATE 6,44,0:PRINT".5"
5150 LOCATE 6,55,0:PRINT"SCREW FEED:    RPM"
5160 LOCATE 7,52,0:PRINT"GAS HEATER"
5170 LOCATE 8,54,0:PRINT"POWER INPUT:     WATTS"
5180 LOCATE 10,52,0:PRINT"ESTIMATED GAS"
5190 LOCATE 11,52,0:PRINT"HEATER OUTLET"
5200 LOCATE 12,54,0:PRINT"TEMPERATURE:     deg C"
5210 LOCATE 13,52,0:PRINT"FINAL TEMP."
5220 LOCATE 14,54,0:PRINT"DILUTED GAS:     deg C"
5230 LOCATE 15,17,0:PRINT"100"
5240 LOCATE 15,29,0:PRINT"0"
5250 LOCATE 15,37,0:PRINT"0"
5260 LOCATE 15,45,0:PRINT"0"
5270 LOCATE 16,2,0:PRINT"MEASURED"
5280 LOCATE 16,52,0:PRINT"SAMPLE BLOCK"
5290 LOCATE 17,2,0:PRINT"SETPOINT"
5300 LOCATE 17,54,0:PRINT"TEMPERATURE:     deg C"
5310 LINE(80,39)-(192,23),,B
5320 LINE(224,39)-(400,23),,B
5330 LINE(88,39)-(120,119),,B
5340 LINE(152,39)-(184,119),,B
5350 LINE(232,39)-(264,119),,B
5360 LINE(296,39)-(328,119),,B
```

```
5360 LINE(296,39)-(328,119),,B
5370 LINE(360,39)-(392,119),,B
5400 LINE(88,118)-(96,110),,BF
5410 LINE-(104,114)
5420 LINE-(96,118)
5430 PAINT(102,114),1
5440 LINE(120,118)-(112,110),,BF
5450 LINE(112,110)-(104,114)
5460 LINE-(112,118)
5470 PAINT(106,114),1
5480 PUT(89,110),MPTR
5490 PUT(112,110),SPTR
5500 GET(88,110)-(104,118),MPTR
5520 GET(104,110)-(120,118),SPTR
5530 YPS1=110:YPS2=110:YPS3=110:YPS4=110:YPS5=110
5540 YPM1=110:YPM2=110:YPM3=110:YPM4=110:YPM5=110
5550 LINE(268,167)-(356,176),,BF
5560 GET (268,167)-(356,176),BLOK
5570 LINE(268,167)-(356,176),0,BF
5580 LOCATE 22,35,0:PRINT"setup mode"
5590 PUT(268,167),BLOK
5600 LOCATE 24,16,0:PRINT"SPACE BAR & BACKSPACE KEYS SELECT SETUP POSITION";
5610 LOCATE 25,8,0:PRINT"u=up d=down U=up*100 D=down*100  [Ctrl]u=up*.1  [Ctrl
=down*.1";
5620 CESHEAD$(1)="PMRL Canmet High Temperature Corrosion-Erosion Test Facility'
5630 CESHEAD$(2)="Designed & constructed by the Centre for Energy Studies, Hal.
ax N.S., 1984"
5640 RETURN
6000 LOCATE 24,15,0:PRINT"                                                    ";
6010 LOCATE 25,1,0:PRINT"
                    ";
6015 LOCATE 20,27,0:PRINT"                                                ";
6020 LINE(268,167)-(356,176),0,BF
6030 LOCATE 22,35,0:PRINT" run mode ";
6040 PUT(268,167),BLOK
6045 INC=1-SAMPOS%:GOSUB 1150:IF SAMPOS%<>1 THEN 6045
6050 GOSUB 50000:STRTM=TIMIN
6055 GOSUB 60400:REM header 1
6060 RETURN
9000 REM initialize Tecmar Labmaster
9010 REM Tecmar Definitions:
9020 TDA1LO%=&H710:REM low byte of d/a #1
9030 TDA1HI%=&H711:REM high byte of d/a #1
9040 TDA2LO%=&H712:REM low byte of d/a #2
9050 TDA2HI%=&H713:REM high byte of d/a #2
9060 TCONTLA%=&H714:REM a/d control/status byte
9070 TADLO%=&H715:REM a/d low byte/channel no. on write
9080 TADHI%=&H716:REM a/d high byte/start convert on write
9090 TDATM%=&H718:REM r/w data port am9513 timer
9100 TMCNTL%=&H719:REM r/w control port am9513 timer
9110 TPPA%=&H71C:REM r/w parallel port A of 8255
9120 TPPB%=&H71D:REM r/w parallel port B of 8255
9130 TPPC%=&H71E:REM r/w parallel port C of 8255
9140 TPPCNTL%=&H71F:REM write 8255 control port
9145 DIM TCDAT(50)
9150 DATA 0,25,49.5,73.6,97.7,122,146.6,171.5
9155 DATA 196.6,246.3,270.8,295.0,319.1,343.0,366.9,390.6
9160 DATA 414.3,437.9,461.5,485.0,508.4,531.9,555.3,578.8
9165 DATA 602.3,625.9,649.5,673.2,697.0,720.8,744.8,769.0
9170 DATA 793.2,817.7,842.3,867.0,891.9,916.9,942.2,967.5
9175 DATA 993.1,1018.8,1044.7,1070.8,1097.1,1123.7,1150.4,1177.4
9180 DATA 1204.7,1232.3
9185 FOR K=0 TO 49
9190 READ TCDAT(K)
9195 NEXT K
```

```
 9210 OUT TCONTLA%,128
 9220 REM init parallel port
 9230 OUT TPPCNTL%,&H90
 9250 REM setup am9513 counter
 9260 REM for rpm measurement with counter #2 (feed screw)
 9270 OUT TMCNTL%,2:REM access mode reg. #2
 9280 REM active high edge trig., repaeting count, up binary 1/16 MHZ
 9290 OUT TDATM%,&HA8:OUT TDATM%,&HDC
 9300 REM same for counter #3 (particle stream chopper)
 9310 OUT TMCNTL%,3:REM access mode reg. #3
 9320 OUT TDATM%,&HA8:OUT TDATM%,&HDC
 9330 REM clear load registers 2&3
 9340 OUT TMCNTL%,&HA:REM access load reg. #2
 9350 OUT TDATM%,0:OUT TDATM%,0:REM clear it
 9360 OUT TMCNTL%,&HB:REM access load reg. #3
 9370 OUT TDATM%,0:OUT TDATM%,0:REM clear it
 9380 REM setup timer #4 for particle velocity:
 9390 REM set t #4 for:
 9400 REM active high level gate,count only during active level,up binary 1mhz
 9410 OUT TMCNTL%,4:REM access mode reg. #4
 9420 OUT TDATM%,&HA8:OUT TDATM%,&H9B
 9430 REM clear load reg. #4
 9440 OUT TMCNTL%,&HC:REM access load reg. #4
 9450 OUT TDATM%,0:OUT TDATM%,0:REM clear it
 9460 REM setup counter #5 for pulse width modulation (gas heater triac )
 9470 OUT TMCNTL%,5:REM access mode reg. #5
 9480 OUT TDATM%,&HA1:OUT TDATM%,&HDC
 9490 REM arm counters 2,3,4,5
 9495 PW%=430:GOSUB 30300
 9500 OUT TMCNTL%,&H3E
 9510 RETURN
 10000 REM read millivolts
 10010 OUT TADLO%,TCHIN%
 10020 OUT TADHI%,0
 10030 WAIT TCONTLA%,128
 10040 TVLL=INP(TADLO%):TVHH=INP(TADHI%)
 10050 TVLL=TVLL AND 255: TVHH=TVHH AND 255
 10060 TMV=(TVLL+256*TVHH)*50/4096
 10070 RETURN
 10100 TCHIN%=3:GOSUB 10000:GASFLO1=TMV:LOCATE 16,30,0:PRINT USING "##.#";GASFL
 10110 PUT(233,YPM3),BLANK,AND:YPM3=110-GASFLO1*1.4:PUT(232,YPM3),MPTR,OR:RETURN
 10200 TCHIN%=4:GOSUB 10000:GASFLO2=TMV*.4:LOCATE 16,38,0:PRINT USING "##.#";GA
 10210 PUT(297,YPM4),BLANK,AND:YPM4=110-GASFLO2*3.5:PUT(296,YPM4),MPTR,OR:RETURN
 10300 TCHIN%=5:GOSUB 10000:GASFLO3=TMV/100:LOCATE 16,46,0:PRINT USING ".###";G
 10310 PUT(361,YPM5),BLANK,AND:YPM5=110-GASFLO3*140:PUT(360,YPM5),MPTR,OR:RETURN
 10400 REM read gas heater input power
 10410 TCHIN%=6:GOSUB 10000:VRMS=TMV*5
 10420 TCHIN%=7:GOSUB 10000:IRMS=TMV/4
 10430 GHW=VRMS*IRMS:LOCATE 7,63,0
 10440 IF IRMS<VRMS/25 AND VRMS>20 THEN GHWSET=0:LOCATE 8,66,0:PRINT USING "###
 ;GHWSET:LOCATE 7,63,0:PRINT "Failure!!" ELSE LOCATE 7,63,0:PRINT "          "
 10450 RETURN
 20000 REM read K type thermocouples
 20010 GOSUB 10000
 20020 TCKI%=INT(TMV):IF TCKI%>50 THEN TCKI%=50
 20030 TCDEGC=TCDAT(TCKI%)+(TCDAT(TCKI%+1)-TCDAT(TCKI%))*(TMV-TCKI%)
 20040 TCHIN%=15:GOSUB 10000:ROOMT=TMV*10-273.15:TCDEGC=TCDEGC+ROOMT
 20050 RETURN
 20100 TCHIN%=0:GOSUB 20000:TC1=TCDEGC:LOCATE 16,12,0:PRINT USING "####";TC1
 20110 PUT(89,YPM1),BLANK,AND:YPM1=110-TC1/16:PUT(88,YPM1),MPTR,OR:RETURN
 20200 TCHIN%=1:GOSUB 20000:TC2=TCDEGC:LOCATE 16,20,0:PRINT USING "####";TC2
 20210 PUT(153,YPM2),BLANK,AND:YPM2=110-TC2/16:PUT(152,YPM2),MPTR,OR:RETURN
 20300 TCHIN%=2:GOSUB 20000:TC3=TCDEGC:LOCATE 17,66,0:PRINT USING "####";TC3:RE
 RN
```

```
:N
'0000 REM read rpm for counter #2
30005 LOCATE 6,66,0:PRINT USING "####";RPM2
 0010 OUT TMCNTL%,&H12
:0020 TLL=INP(TDATM%):THH=INP(TDATM%)
30025 IF (TLL OR THH)=0 THEN RPM2=0:RETURN
 30030 RPM2=60*62500!/(256*THH+TLL)
 0035 IF RPM2>10000 THEN RPM2=0
30037 IF RPM2<PFRPMN THEN PFRPMN=RPM2
30038 IF RPM2>PFRPMX THEN PFRPMX=RPM2
 0040 RETURN
:0100 REM read rpm for counter #3
30105 LOCATE 2,53,0
 30107 IF SAMPOS%=0 THEN PRINT USING "CHOPPER #### RPM";RPM3 ELSE PRINT"
       "
30110 OUT TMCNTL%,&H13
 30120 TLL=INP(TDATM%):THH=INP(TDATM%)
30125 IF (TLL OR THH)=0 THEN RPM3=0: RETURN
30130 RPM3=30*62500!/(256*THH+TLL)
30135 IF RPM3>10000 THEN RPM3=0
 30140 RETURN
30200 REM read particle velocity counter #4
30210 OUT TMCNTL%,&H14
 30220 TLL=INP(TDATM%):THH=INP(TDATM%)
 30230 TDELAY=TLL+256*THH
30233 WPV=PVMEDR
30235 IF TDELAY=0 OR TDELAY>1.4E+07/(RPM3+1) THEN PVEL=0:WPV=.1*PVMEDR:GOTO 30.
 4
30240 PVEL=(DIST/TDELAY)*1000000!
30243 IF PVEL>999 THEN PVEL =0
 30244 MPV=MPV+WPV*SGN(PVEL-MPV)
 30245 LOCATE 1,43,0:PRINT USING "###.#";MPV
30250 RETURN
 30300 REM set pulse width
 30310 OUT TMCNTL%,&HD
30320 OUT TDATM%,FNLO(PW%)
30330 OUT TDATM%,FNHI(PW%)
 30340 RETURN
 30400 REM output to dac 1
30410 DACN%=(4.9-DAC1V)*2048/5
30420 OUT TDA1HI%,FNHI(DACN%):OUT TDA1LO%,FNLO(DACN%)
 30430 RETURN
30500 REM output to dac 2
30510 DACN%=DAC2V*2048/5
 30520 OUT TDA2HI%,FNHI(DACN%):OUT TDA2LO%,FNLO(DACN%)
 30530 RETURN
40000 REM select gas valve channel (lines 0,1 8255 port B)
40010 PBDAT%=(PBDAT% AND &HFC) OR (GVCHAN% AND 3)
 40020 OUT TPPB%,PBDAT%
40030 RETURN
40100 REM furnace control and safety shutoff
 40110 REM heater #1 on
40120 PBDAT%=PBDAT% OR 4
40130 OUT TPPB%,PBDAT%
40140 RETURN
 40200 REM heater #2 on
40210 PBDAT%=PBDAT% OR 8
40220 OUT TPPB%,PBDAT%
 40230 RETURN
40300 REM heater #1 off
40310 PBDAT%=PBDAT% AND NOT(4)
40320 OUT TPPB%,PBDAT%
 40330 RETURN
40400 REM heater #2 off
40410 PBDAT%=PBDAT% AND NOT(8)
```

```
40430 RETURN
40500 REM toggle safety shutoff (pb7).
40505 LOCATE 2,71,0:PRINT TIME$
40510 IF ST%=128 THEN 40540
40520 PBDAT%=PBDAT% AND ST%
40530 GOTO 40550
40540 PBDAT%=PBDAT% OR ST%
40550 OUT TPPB%,PBDAT%
40560 ST%=NOT(ST%)
40570 RETURN
40600 REM move sample position motor
40610 IF INC=0 THEN RETURN
40620 SPEED=50:SKIP%=SKIP
40625 GOSUB 50000:STM=TIMIN
40630 FOR I=1 TO 200
40640 PLAY "o0l64g"
40650 GOSUB 40500:GOSUB 40800
40660 IF ARRIVED THEN LOCATE 19,44,0:PRINT"er":GOTO 40750
40665 GOSUB 50000:IF TIMIN>STM+FASPDM THEN 40680
40670 NEXT I
40680 SPEED=15:SKIP%=0
40690 FOR I=1 TO SLOSPD%
40700 GOSUB 40500:GOSUB 40800
40710 IF ARRIVED THEN 40750
40720 NEXT I
40730 PBDAT%=PBDAT% AND &H8F:OUT TPPB%,PBDAT%
40750 INC=0:RETURN
40800 PBDAT%=PBDAT% AND &H8F:ARRIVED=0
40810 OUT TPPB%,PBDAT%
40820 IF INC>0 THEN PBDAT%=PBDAT% OR &H10
40830 IF INC<0 THEN PBDAT%=PBDAT% OR &H40
40835 OUT TPPB%,PBDAT%
40840 FOR J=1 TO 50
40850 IF J>=SPEED THEN OUT TPPB%,PBDAT% AND &H8F
40855 IF I<SKIP% THEN 40870
40860 IF (INP(TPPA%) AND 1) THEN ARRIVED=1:PBDAT%=PBDAT% AND &H8F:OUT TPPB%,PB
T%:RETURN
40870 NEXT J
40880 RETURN
40900 PLAY "o5L2a":LOCATE 20,27,0:IF ERR=27 OR ERR=24 THEN PRINT "   printer i
off !  " ELSE PRINT "error #";ERR;"in line";ERL
40910 EXPROC=0:COMM$="":RESUME 1000
50000 REM time convert
50010 T$=TIME$
50020 TIMIN=60*VAL(MID$(T$,1,2))+VAL(MID$(T$,4,2))+VAL(MID$(T$,7,2))/60+CLKROL
50030 IF TIMIN<PTIMIN THEN CLKROL=PTIMIN
50040 PTIMIN=TIMIN
50050 EXPTM=TIMIN-STRTM
50060 RETURN
55000 REM wind down
55005 IF DONE THEN 55100
55010 FOR K=1 TO 5:INC=-1:GOSUB 40600:NEXT :INC=1:GOSUB 40600
55015 SAMPOS%=1:LOCATE 19,44,0:PRINT USING "##";SAMPOS%
55020 RPMSET=0:GOSUB 1170
55030 OTSET1=TSET1:TSET1=0:GOSUB 1200
55040 OTSET2=TSET2:TSET2=0:GOSUB 1250
55045 OHGASV=HGASV:OTGHOUT=TGHOUT:OTGAS=TGAS
55050 OGHWSET=GHWSET:GHWSET=0:GOSUB 1450
55060 DONE=1
55100 LOCATE 20,27,0:IF TC2<500 THEN EXPROC=0:PRINT"
          " ELSE PRINT"WARNING ! Don't shut off cooling water yet."
55120 IF DONE=2 THEN 1000
55130 DONE=2
55140 OGASET1=GASET1:GASET1=0:GOSUB 1300
55150 OGASET2=GASET2:GASET2=0:GOSUB 1350
55160 OGASET3=GASET3:GASET3=0:GOSUB 1400
55170 PLAY "cbcbcbcbcbcbcbcbcbcbcbcbc"
```

OPERATOR: G.J.Murphy 02-27-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENT REPORT

TEST GAS COMPOSITION:

nitrogen....	100.0 %
oxygen....	0.0 %
carbon dioxide....	0.0 %
carbon monoxide....	0.0 %
water vapor....	0.0 %
sulfur dioxide....	0.0 %

TEST CONDITIONS:

main fornace temperature:	20 C
pre-heat furnace temperature:	20 C
input power to gas heater:	0 WATTS
main gas flow:	15.0 lpm
particle feeder gas flow:	9.0 lpm
SO2 gas flow:	.000 lpm

ERODANT TYPE: SiO2 170 microns

ERODE TIME PER SAMPLE: 30 minutes

POWDER FEED AUGER RPM:
minimum during run: 0
maximum during run: 1138.088

ESTIMATED GAS TEMPS:

from gas heater:	25 C
after particle entrainmemt:.	25 C

ESTIMATED GAS VELOCITY: 24.6 m/s

MEASURED PARTICLE VELOCITY: 5.0 m/s

SAMPLE DISCRIPTIONS:

sample no. 1 : 304ss 0 deg
sample no. 2 : 304ss 30 deg
sample no. 3 : 304ss 45 deg
sample no. 4 : 304ss 60 deg

GENERAL NOTES:

acceptance test one ambient T 1.9 g/m 5M/s

OPERATOR: G.J.Murphy DATE: 02-27-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENTAL CONDITION VERIFICATION

	Temperatures deg C			Gas flows lpm			auger
time	main	pre-heat	sample block	main	powder feed	SO2	rpm
16:54:50	22	22	22	15.0	7.5	.002	73
			SAMPLE # 1				
16:55:31	21	22	21	14.9	7.4	.001	69
16:56:31	22	23	23	15.1	7.5	.003	70
16:57:31	21	21	21	15.0	7.4	.001	69
16:58:31	21	22	22	14.9	7.5	.001	69
16:59:31	23	23	23	15.2	7.6	.003	69
17:00:31	22	22	22	14.9	7.5	.001	69
17:01:31	23	23	23	15.2	7.6	.003	69
17:02:31	22	22	22	14.9	7.6	.001	69
17:03:31	23	23	23	15.1	7.7	.003	69
17:04:31	22	22	22	14.9	7.6	.002	69
17:05:31	22	22	22	15.0	7.6	.001	69
17:06:31	23	23	23	15.1	7.7	.004	69
17:07:31	22	22	22	14.9	7.7	.001	69
17:08:31	23	23	22	14.9	7.7	.001	69
17:09:31	22	22	22	15.0	7.7	.002	0
17:10:31	23	23	23	15.1	7.8	.004	0
17:11:31	22	22	22	14.9	7.7	.002	70
17:12:31	23	23	23	15.1	7.8	.003	0
17:13:31	22	22	22	14.9	7.8	.002	0
17:14:31	23	23	23	15.1	7.8	.002	70
17:15:31	22	22	22	14.9	7.8	.002	0
17:16:31	23	23	23	15.1	7.9	.003	69
17:17:31	23	23	23	15.1	7.9	.003	69
17:18:31	22	22	23	15.1	7.8	.002	0
17:19:31	23	23	23	15.1	7.9	.003	0
17:20:31	23	23	23	15.1	7.9	.004	0
17:21:31	23	23	24	15.0	7.9	.003	69
17:22:31	23	23	23	15.0	7.9	.003	70
17:23:31	22	22	22	14.9	7.9	.001	70
17:24:31	23	23	23	14.9	7.9	.002	69
			SAMPLE # 2				
17:25:31	23	23	23	14.9	7.9	.001	0
17:26:31	24	23	23	15.1	7.9	.002	70
17:27:31	24	23	24	15.0	8.0	.003	69
17:28:31	23	23	23	15.0	7.9	.001	70
17:29:31	23	23	23	15.1	8.0	.003	69
17:30:31	24	24	24	15.1	8.0	.003	70
17:31:31	23	23	23	15.0	8.0	.003	69
17:32:31	23	23	23	15.0	8.0	.002	69
17:33:31	24	24	24	15.1	8.0	.003	70
17:34:31	24	23	23	14.9	8.0	.002	69
17:35:31	23	23	23	14.6	8.0	.002	70
17:36:31	24	24	24	15.0	8.0	.004	69
17:37:31	23	23	23	15.0	8.0	.002	69
17:38:31	23	23	23	14.9	8.0	.004	70
17:39:31	23	23	23	14.9	8.0	.002	69
17:40:31	24	24	24	14.9	8.1	.003	70
17:41:31	23	23	23	14.8	8.0	.002	69
17:42:31	24	24	24	14.9	8.1	.003	69

17:43:31	23	23	23	15.0	8.0	.002	70
17:44:31	24	24	24	15.0	8.1	.003	70
17:45:31	24	24	24	15.1	8.1	.003	70
17:46:31	23	23	23	14.9	8.1	.002	69
17:47:31	23	23	23	15.1	8.1	.002	70
17:48:31	24	24	24	15.0	8.1	.003	69
17:49:31	23	23	23	14.9	8.1	.002	69
17:50:31	23	23	23	15.0	8.1	.002	70
17:51:31	23	24	25	15.0	8.2	.003	70
17:52:31	24	24	24	15.3	8.2	.003	71
17:53:31	23	23	23	15.0	8.1	.002	66
17:54:31	23	23	23	14.9	8.2	.002	70
			SAMPLE # 3				
17:55:31	23	24	23	14.9	8.2	.002	70
17:56:31	24	24	24	15.1	8.3	.003	69
17:57:31	23	23	23	14.8	8.2	.002	70
17:58:31	24	24	24	15.0	8.3	.003	76
17:59:31	24	24	24	15.1	8.3	.003	70
18:00:31	23	23	23	15.0	8.2	.002	70
18:01:31	23	23	24	14.9	8.2	.002	71
18:02:31	23	23	23	15.1	8.3	.003	66
18:03:31	23	23	23	14.9	8.3	.002	66
18:04:31	24	24	25	15.1	8.4	.003	66
18:05:31	24	24	24	14.8	8.3	.002	71
18:06:31	24	25	25	15.1	8.4	.004	71
18:07:31	23	24	24	15.0	8.3	.002	70
18:08:31	24	24	24	14.9	8.3	.002	70
18:09:31	25	24	24	15.0	8.4	.004	71
18:10:31	24	24	24	15.0	8.4	.003	76
18:11:31	25	24	24	15.0	8.5	.003	70
18:12:31	24	24	24	14.9	8.4	.002	70
18:13:31	24	25	25	15.1	8.5	.004	72
18:14:31	24	24	24	15.0	8.4	.002	66
18:15:31	24	24	24	14.9	8.5	.002	71
18:16:31	25	24	24	15.1	8.5	.002	71
18:17:31	24	24	24	15.1	8.6	.004	76
18:18:31	23	24	24	14.9	8.5	.002	71
18:19:31	24	25	25	14.9	8.6	.003	71
18:20:31	24	24	24	14.9	8.5	.002	71
18:21:31	25	25	25	15.1	8.6	.004	76
18:22:31	24	24	24	14.9	8.6	.002	71
18:23:31	24	24	24	14.9	8.6	.002	71
18:24:31	24	24	24	14.8	8.6	.002	72
			SAMPLE # 4				
18:25:31	24	24	24	14.9	8.6	.003	71
18:26:31	24	24	24	14.9	8.6	.002	71
18:27:31	25	24	24	14.9	8.6	.002	71
18:28:31	24	24	24	14.9	8.7	.002	71
18:29:31	24	24	24	14.9	8.7	.002	71
18:30:31	24	24	25	15.2	8.7	.003	71
18:31:31	25	25	25	15.1	8.8	.002	71
18:32:31	24	24	24	14.9	8.7	.002	72
18:33:31	25	25	25	15.1	8.8	.003	71
18:34:31	25	25	25	15.2	8.8	.003	0
18:35:31	24	24	24	15.0	8.8	.002	72
18:36:31	25	25	25	15.0	8.9	.004	0
18:37:31	24	24	24	14.8	8.8	.002	0
18:38:31	25	25	24	14.9	8.8	.002	72
18:39:31	24	25	25	14.9	8.9	.004	72
18:40:31	24	24	24	15.0	8.8	.002	77
18:41:31	24	24	24	14.7	8.9	.002	72
18:42:31	25	25	25	15.1	8.9	.003	67
18:43:31	25	25	25	15.1	8.9	.003	71
18:44:31	24	24	24	14.9	8.9	.002	72
18:45:31	24	24	25	15.3	9.0	.003	71
18:46:31	25	25	24	14.9	8.9	.002	71

18:47:31	25	25	25	15.0	9.0	.003	72
18:48:31	24	24	24	15.1	9.0	.002	72
18:49:31	24	25	25	15.0	9.0	.004	72
18:50:31	25	25	25	15.1	9.1	.004	77
18:51:31	24	24	24	14.7	9.0	.002	72
18:52:31	24	24	24	14.9	9.1	.004	72
18:53:31	25	25	25	15.1	9.1	.004	72
18:54:31	25	25	25	15.1	9.1	.003	71

OPERATOR: G.J.M. 01-01-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENT REPORT

TEST GAS COMPOSITION:

nitrogen....	100.0 %
oxygen....	0.0 %
carbon dioxide....	0.0 %
carbon monoxide....	0.0 %
water vapor....	0.0 %
sulfur dioxide....	0.0 %

TEST CONDITIONS:

main fornace temperature:	1040 C
pre-heat furnace temperature:	970 C
input power to gas heater:	850 WATTS
main gas flow:	49.0 lpm
particle feeder gas flow:	14.6 lpm
SO2 gas flow:	.000 lpm

ERODANT TYPE: silica 170 micron

ERODE TIME PER SAMPLE: 20 minutes

POWDER FEED AUGER RPM:
minimum during run: 63.98225
maximum during run: 368.6228

ESTIMATED GAS TEMPS:

from gas heater: 767 C
after particle entrainmemt: 611 C

ESTIMATED GAS VELOCITY: 184.1 m/s

MEASURED PARTICLE VELOCITY: 20.2 m/s

SAMPLE DISCRIPTIONS:

sample no. 1 : 304ss
sample no. 2 : 304ss
sample no. 3 : 304ss
sample no. 4 : 304ss

GENERAL NOTES:

acceptance tests 1000 deg C nominal velocity 40 M/s samples 1 & 2 1.7 g/s
samples 3 & 4 10 g/s 170 micron erodant

OPERATOR: G.J.M. DATE: 01-01-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENTAL CONDITION VERIFICATION

	Temperatures deg C			Gas flows lpm			auger
time	main	pre-heat	sample block	main	powder feed	???	rpm
14:09:56	1035	966	967	50.0	13.6	.000	67
			SAMPLE # 1				
14:10:37	1034	953	995	48.9	13.6	.000	68
14:11:37	1033	952	1009	48.8	13.6	.000	67
14:12:37	1030	949	1009	48.9	13.6	.000	68
14:13:37	1024	947	1009	48.8	13.6	.000	67
14:14:37	1026	946	1041	48.9	13.6	.000	66
14:15:37	1026	940	1009	48.8	13.5	.000	66
14:16:37	1025	939	1007	48.7	13.6	.000	68
14:17:37	1024	939	1005	48.6	13.6	.000	68
14:18:37	1024	934	1006	48.6	13.7	.000	67
14:19:37	1027	938	1004	48.2	13.8	.000	68
14:20:37	1023	936	1005	48.6	13.8	.000	68
14:21:37	1025	937	1002	48.1	13.8	.000	68
14:22:37	1023	941	1009	48.8	13.9	.000	68
14:23:37	1021	940	1006	48.6	13.9	.000	67
14:24:37	1023	940	1007	48.7	13.9	.000	66
14:25:37	1021	940	1006	48.6	14.0	.000	68
14:26:37	1024	941	1005	48.7	14.1	.000	68
14:27:37	1024	936	1007	48.6	13.9	.000	67
14:28:37	1027	943	1009	48.8	14.1	.000	68
14:29:37	1026	937	1009	48.6	13.9	.000	68
			SAMPLE # 2				
14:30:37	1024	940	1008	48.6	14.2	.000	67
14:31:37	1026	942	1007	48.3	14.3	.000	68
14:32:37	1026	939	1007	48.4	14.0	.000	68
14:33:37	1027	940	1010	48.6	14.2	.000	68
14:34:37	1024	939	1007	48.4	14.3	.000	68
14:35:37	1025	940	1008	48.4	14.4	.000	67
14:36:37	1021	939	1007	48.4	14.4	.000	67
14:37:37	1025	941	1008	48.4	14.4	.000	68
14:38:37	1023	936	1007	48.3	14.4	.000	67
14:39:37	1025	938	1008	48.3	14.3	.000	67
14:40:37	1022	938	1007	48.3	14.5	.000	68
14:41:37	1023	939	1009	48.2	14.5	.000	68
14:42:37	1023	941	1008	48.4	14.6	.000	68
14:43:37	1024	936	1007	48.2	14.6	.000	67
14:44:37	1021	945	1007	48.2	14.6	.000	67
14:45:37	1025	940	1007	48.2	14.7	.000	68
14:46:37	1025	939	1009	48.2	14.7	.000	68
14:47:37	1023	939	1008	48.1	14.5	.000	67
14:48:37	1025	940	1010	48.3	14.7	.000	70
14:49:37	1026	941	1009	48.2	14.8	.000	68
			SAMPLE # 3				
14:50:37	1026	937	1007	47.9	14.4	.000	314
14:51:37	1026	938	1010	47.9	14.3	.000	317
14:52:37	1024	937	1004	47.8	14.4	.000	316
14:53:37	1022	935	1004	47.8	14.4	.000	309
14:54:37	1023	935	1004	47.5	14.3	.000	314
14:55:37	1024	938	1004	47.5	14.1	.000	313
14:56:37	1025	938	1001	47.1	14.4	.000	317
14:57:37	1024	937	1004	47.6	14.7	.000	314

14:58:37	1024	941	1004	47.6	14.7	.000	314
14:59:37	1026	936	1006	47.5	14.6	.000	314
15:00:37	1025	939	1004	47.3	14.8	.000	315
15:01:37	1026	939	1004	47.4	14.9	.000	316
15:02:37	1027	939	1007	47.5	14.9	.000	314
15:03:37	1025	939	1008	47.5	14.9	.000	318
15:04:37	1025	939	1008	47.6	15.0	.000	317
15:05:37	1027	938	1009	47.6	15.0	.000	317
15:06:37	1028	939	1010	47.6	15.1	.000	318
15:07:37	1024	938	1008	47.5	15.1	.000	315
15:08:37	1024	940	1010	47.5	15	.000	323
15:09:37	1027	936	1007	47.4	15.1	.000	319
			SAMPLE # 4				
15:10:37	1024	937	1011	47.4	15.3	.000	316
15:11:37	1025	935	1012	47.4	15.3	.000	320
15:12:37	1024	941	1011	47.6	15.4	.000	319
15:13:37	1023	940	1012	47.5	13.9	.000	316
15:14:37	1024	943	1013	47.7	13.9	.000	319
15:15:37	1025	936	1012	47.6	13.9	.000	319
15:16:37	1026	942	1013	47.6	13.9	.000	313
15:17:37	1026	940	1011	47.5	14.0	.000	318
15:18:37	1027	943	1016	47.6	14.0	.000	317
15:19:37	1027	938	1014	47.4	14.0	.000	319
15:20:37	1027	943	1013	47.6	14.1	.000	323
15:21:37	1027	936	1013	47.4	13.9	.000	322
15:22:37	1027	940	1011	47.5	14.2	.000	319
15:23:37	1028	939	1012	47.4	14.1	.000	319
15:24:37	1026	939	1013	47.4	14.2	.000	320
15:25:37	1026	940	1012	47.5	14.3	.000	317
15:26:37	1026	937	1013	47.5	14.2	.000	318
15:27:37	1024	940	1013	47.5	14.4	.000	316
15:28:37	1026	936	1012	47.4	14.3	.000	319
15:29:37	1025	942	1010	47.6	14.5	.000	315

OPERATOR: G.J.M. 03-01-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENT REPORT

TEST GAS COMPOSITION:

nitrogen....	100.0 %
oxygen....	0.0 %
carbon dioxide....	0.0 %
carbon monoxide....	0.0 %
water vapor....	0.0 %
sulfur dioxide....	0.0 %

TEST CONDITIONS:

main fornace temperature:	1010 C
pre-heat furnace temperature:	1010 C
input power to gas heater:	200 WATTS
main gas flow:	12.0 lpm
particle feeder gas flow:	14.9 lpm
SO2 gas flow:	.000 lpm

ERODANT TYPE: silica 170 microns

ERODE TIME PER SAMPLE: 30 minutes

POWDER FEED AUGER RPM:
minimum during run: 0
maximum during run: 332.8008

ESTIMATED GAS TEMPS:

from gas heater: 715 C

area particle entrainment: 38.7 %

ESTIMATED GAS VELOCITY: 57.3 m/s

MEASURED PARTICLE VELOCITY: 10.3 m/s

SAMPLE DISCRIPTIONS:

sample no. 1 : 304ss
sample no. 2 : 304ss
sample no. 3 : 304ss
sample no. 4 : 304ss

GENERAL NOTES:

acceptance tests 1000 deg C nominal velocity 10 M/s samples 1 and 2 1.7 g/s
samples 3 and 4 10 g/s 170 micron erodant

OPERATOR: G.J.M. DATE: 03-01-1984

PMRL Canmet High Temperature Corrosion-Erosion Test Facility
Designed & constructed by the Centre for Energy Studies, Halifax N.S., 1984

EXPERIMENTAL CONDITION VERIFICATION

	Temperatures deg C			Gas flows lpm			auger
time	main	pre-heat	sample block	main	powder feed	SO2	rpm
16:11:09	1004	997	902	11.7	13.1	.003	72
			SAMPLE # 1				
16:11:50	1001	995	962	12.3	13.1	.003	72
16:12:50	999	989	982	11.8	13.1	.003	72
16:13:50	1000	987	986	12.0	13.1	.002	72
16:14:50	999	990	986	11.9	13.2	.000	72
16:15:50	1000	987	985	11.9	13.2	.000	72
16:16:50	1000	988	988	12.4	13.2	.002	72
16:17:50	1000	987	985	11.8	13.3	.004	72
16:18:50	1000	985	988	12.0	13.3	.002	72
16:19:50	995	986	987	12.5	13.2	.001	72
16:20:50	1001	982	989	12.1	13.4	.003	72
16:21:50	998	985	986	11.9	13.3	.002	72
16:22:50	998	985	986	12.3	13.3	.001	72
16:23:50	1001	980	989	12.6	13.4	.003	72
16:24:50	995	984	986	12.2	13.4	.002	72
16:25:50	1000	983	983	11.8	13.4	.001	72
16:26:50	996	984	986	12.2	13.5	.001	72
16:27:50	999	984	986	12.3	13.5	.000	72
16:28:50	996	983	986	12.2	13.5	.001	72
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

16:29:50	999	980	987	12.7	13.6	.001	72
16:30:50	1000	983	986	12.2	13.6	.003	72
16:31:50	1000	981	987	12.1	13.6	.001	72
16:32:50	999	980	987	12.7	13.6	.001	72
16:33:50	999	984	985	12.4	13.7	.000	72
16:34:50	996	983	987	12.0	13.6	.001	68
16:35:50	999	980	987	11.4	13.9	.002	64
16:36:50	999	985	991	11.9	14.0	.003	63
16:37:50	995	982	986	12.0	13.9	.001	63
16:38:50	999	984	987	12.2	13.9	.002	63
16:39:50	1001	986	987	12.4	14.0	.000	63
16:40:50	995	983	986	12.3	13.9	.001	64
			SAMPLE # 2				
16:41:50	1000	982	988	12.2	14.1	.004	64
16:42:50	1002	982	986	12.3	14.0	.000	64
16:43:50	999	980	987	12.5	12.6	.002	62
16:44:50	1000	985	986	11.9	13.0	.000	70
16:45:50	997	981	983	11.6	12.9	.000	70
16:46:50	1000	981	982	11.8	12.9	.002	71
16:47:50	997	985	988	12.2	13.0	.003	71
16:48:50	999	982	984	11.3	13.0	.000	71
16:49:50	1000	984	988	12.0	13.1	.003	69
16:50:50	1001	988	987	12.3	13.1	.000	70
16:51:50	1000	985	987	12.3	13.1	.003	70
16:52:50	995	984	986	12.3	13.2	.002	71
16:53:50	999	984	988	12.1	13.2	.003	70
16:54:50	999	985	983	11.6	13.2	.003	70
16:55:50	999	986	987	12.3	13.2	.002	69
16:56:50	996	984	987	12.3	13.2	.000	68
16:57:50	998	980	983	12.1	13.3	.000	70
16:58:50	998	980	986	12.0	13.3	.002	70
16:59:50	995	983	985	12.0	13.3	.001	71
17:00:50	999	983	987	12.4	13.4	.003	70
17:01:50	999	985	988	11.9	13.4	.002	71
17:02:50	999	984	987	12.7	13.4	.004	70
17:03:50	999	983	986	12.2	13.4	.002	70
17:04:50	1001	985	982	10.9	13.5	.002	70
17:05:50	1000	983	987	12.0	13.6	.003	70
17:06:50	1001	986	987	12.3	13.6	.004	70
17:07:50	999	984	985	12.2	13.6	.002	71
17:08:50	1001	984	984	11.5	13.6	.003	70
17:09:50	995	993	985	12.0	13.6	.002	70
17:10:50	998	983	986	12.2	13.6	.002	70
			SAMPLE # 3				
17:11:50	997	980	982	11.9	13.2	.002	321
17:12:50	994	978	983	12.0	13.3	.002	321
17:13:50	994	979	982	12.2	13.7	.003	320
17:14:50	1000	979	986	12.6	13.9	.004	323
17:15:50	997	983	983	12.5	13.3	.003	322
17:16:50	997	981	981	12.0	13.2	.003	323
17:17:50	1002	983	983	12.1	13.3	.003	323
17:18:50	999	980	981	12.5	13.2	.003	321
17:19:50	998	980	985	11.7	13.2	.006	323
17:20:50	999	986	985	12.1	13.4	.008	323
17:21:50	1000	983	983	11.9	13.3	.007	324
17:22:50	999	985	984	12.0	13.4	.007	323
17:23:50	999	984	985	12.1	13.5	.009	325
17:24:50	997	985	982	11.9	13.5	.004	325
17:25:50	1000	983	986	12.0	13.5	.007	323
17:26:50	995	984	983	12.0	13.5	.008	324
17:27:50	998	981	985	12.0	13.6	.008	323
17:28:50	999	984	986	12.1	13.6	.008	326
17:29:50	996	986	982	12.0	13.7	.003	326
17:30:50	1000	987	983	12.0	13.7	.004	325
17:31:50	998	984	984	12.1	13.7	.008	327
17:32:50	1001	985	984	12.1	13.5	.007	319

17:33:50	997	982	985	12.1	13.8	.007	328
17:34:50	1000	985	983	11.9	13.8	.007	327
17:35:50	1000	983	984	12.0	13.8	.007	328
17:36:50	998	984	987	12.1	13.9	.009	329
17:37:50	1000	982	986	11.9	13.8	.007	328
17:38:50	1000	981	984	11.9	13.9	.007	328
17:39:50	1000	986	986	12.2	14.0	.010	327
17:40:50	999	986	982	12.1	14.0	.003	330
			SAMPLE # 4				
17:41:50	1001	982	986	12.2	14.0	.004	328
17:42:50	996	990	986	12.1	14.0	.007	331
17:43:50	997	980	984	11.9	14.1	.008	327
17:44:50	995	982	984	12.0	14.1	.008	330
17:45:50	1000	983	986	12.2	14.2	.005	327
17:46:50	999	982	984	11.8	14.2	.008	325
17:47:50	997	983	985	11.9	14.2	.008	325
17:48:50	996	982	987	12.0	14.2	.009	327
17:49:50	999	983	985	12.0	14.2	.003	328
17:50:50	995	982	986	11.9	14.3	.008	328
17:51:50	1001	985	989	12.0	14.4	.008	329
17:52:50	999	985	984	11.6	14.4	.007	328
17:53:50	997	984	987	12.1	14.3	.007	328
17:54:50	998	985	986	12.3	14.4	.009	328
17:55:50	997	984	986	12.2	14.4	.008	327
17:56:50	994	983	985	12.2	14.5	.007	329
17:57:50	999	980	987	11.9	14.5	.008	329
17:58:50	997	990	985	11.9	14.6	.008	330
17:59:50	998	984	984	11.8	14.6	.008	328
18:00:50	996	983	985	12.1	14.6	.007	331
18:01:50	996	986	988	12.0	14.6	.008	326
18:02:50	997	985	986	12.1	14.6	.007	331
18:03:50	999	982	983	12.0	14.7	.003	331
18:04:50	998	987	986	12.1	14.7	.007	330
18:05:50	999	980	987	12.1	14.7	.007	329
18:06:50	999	982	988	12.2	14.8	.008	330
18:07:50	997	982	985	11.9	14.9	.009	330
18:08:50	996	979	984	11.9	14.8	.008	331
18:09:50	998	980	987	12.0	14.9	.007	331
18:10:50	1000	981	985	12.2	14.9	.004	330